# 2. Trends in Greenhouse Gas Emissions

## *2.1. Recent Trends in U.S. Greenhouse Gas Emissions*

In 2004, total U.S. greenhouse gas emissions were 7,074.4 teragrams of carbon dioxide equivalents (Tg $CO_2$ Eq.)[1]. Overall, total U.S. emissions have risen by 15.8 percent from 1990 to 2004, while the U.S. gross domestic product has increased by 51 percent over the same period (BEA 2005). Emissions rose from 2003 to 2004, increasing by 1.7 percent (115.3 Tg $CO_2$ Eq.). The following factors were primary contributors to this increase: 1) robust economic growth in 2004, leading to increased demand for electricity and fossil fuels, 2) expanding industrial production in energy-intensive industries, also increasing demand for electricity and fossil fuels, and 3) increased travel, requiring higher rates of consumption of petroleum fuels.[2] Figure 2-1 through Figure 2-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute changes since 1990.

Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

Figure 2-3: Cumulative Change in U.S. Greenhouse Gas Emissions Relative to 1990

As the largest source of U.S. greenhouse gas emissions, carbon dioxide ($CO_2$) from fossil fuel combustion has accounted for approximately 80 percent of global warming potential (GWP) weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2003 and 2004. Emissions from this source category grew by 20.4 percent (960.0 Tg $CO_2$ Eq.) from 1990 to 2004 and were responsible for most of the increase in national emissions during this period. From 2003 to 2004, these emissions increased by 85.5 Tg $CO_2$ Eq. (1.5 percent), slightly greater than the source's average annual growth rate of 1.3 percent from 1990 through 2004. Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Changes in $CO_2$ emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States generally fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

In the longer-term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses), the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs) and consumer behavior (e.g., walking, bicycling, or telecommuting to work instead of driving).

[1] Estimates are presented in units of teragrams of carbon dioxide equivalent (Tg $CO_2$ Eq.), which weight each gas by its Global Warming Potential, or GWP, value. (See section on Global Warming Potentials, Chapter 1.)

[2] See the following section for an analysis of emission trends by general economic sector.

Energy-related $CO_2$ emissions also depend on the type of fuel or energy consumed and its carbon intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the $CO_2$ because of the lower carbon content of natural gas. Table 2-1 shows annual changes in emissions during the last five years for coal, petroleum, and natural gas in selected sectors.

Table 2-1: Annual Change in $CO_2$ Emissions from Fossil Fuel Combustion for Selected Fuels and Sectors (Tg $CO_2$ Eq. and Percent)

| **Sector** | **Fuel Type** | **2000 to 2001** | | **2001 to 2002** | | **2002 to 2003** | | **2003 to 2004** | |
|---|---|---|---|---|---|---|---|---|---|
| Electricity Generation | Coal | -50.7 | -3% | 3.8 | 0% | 37.5 | 2% | 9.9 | 1% |
| Electricity Generation | Natural Gas | 8.2 | 3% | 16.1 | 6% | -28.0 | -9% | 18.2 | 7% |
| Electricity Generation | Petroleum | 10.5 | 12% | -23.7 | -23% | 19.2 | 25% | 0.3 | 0% |
| Transportation[a] | Petroleum | -11.7 | -1% | 42.0 | 2% | 2.0 | 0% | 54.3 | 3% |
| Residential | Natural Gas | -10.2 | -4% | 6.6 | 3% | 11.4 | 4% | -11.4 | -4% |
| Commercial | Natural Gas | -6.9 | -4% | 5.9 | 4% | 4.6 | 3% | -12.7 | -7% |
| Industrial | Coal | -1.1 | -1% | -9.7 | -8% | 1.4 | 1% | -0.7 | -1% |
| Industrial | Natural Gas | -36.8 | -8% | 6.3 | 1% | -15.0 | -3% | 12.3 | 3% |
| **All Sectors[b]** | **All Fuels[b]** | **-46.8** | **-1%** | **14.9** | **0%** | **69.3** | **1%** | **85.5** | **2%** |

[a] Excludes emissions from International Bunker Fuels.
[b] Includes fuels and sectors not shown in table.

In 2001, economic growth in the United States slowed considerably for the second time since 1990, contributing to a decrease in $CO_2$ emissions from fossil fuel combustion, also for the second time since 1990. A significant reduction in industrial output contributed to weak economic growth, primarily in manufacturing, and led to lower emissions from the industrial sector. Several other factors also played a role in this decrease in emissions. Warmer winter conditions compared to 2000, along with higher natural gas prices, reduced demand for heating fuels. Additionally, nuclear facilities operated at a very high capacity, offsetting electricity produced from fossil fuels. Since there are no greenhouse gas emissions associated with electricity production from nuclear plants, this substitution reduces the overall carbon intensity of electricity generation.

Emissions from fuel combustion resumed a modest growth in 2002, slightly less than the average annual growth rate since 1990. There were a number of reasons behind this increase. The U.S. economy experienced moderate growth, recovering from weak conditions in 2001. Prices for fuels remained at or below 2001 levels; the cost of natural gas, motor gasoline, and electricity were all lower–triggering an increase in demand for fuel. In addition, the United States experienced one of the hottest summers on record, causing a significant increase in electricity use in the residential sector as the use of air-conditioners increased. Partially offsetting this increased consumption of fossil fuels, however, were increases in the use of nuclear and renewable fuels. Nuclear facilities operated at the highest capacity on record in 2002. Furthermore, there was a considerable increase in the use of hydroelectric power in 2002 after a very low output the previous year.

Emissions from fuel combustion continued growing in 2003, at about the average annual growth rate since 1990. A number of factors played a major role in the magnitude of this increase. The U.S. economy experienced moderate growth from 2002, causing an increase in the demand for fuels. The price of natural gas escalated dramatically, causing some electric power producers to switch to coal, which remained at relatively stable prices. Colder winter conditions brought on more demand for heating fuels, primarily in the residential sector. Though a cooler summer partially offset demand for electricity as the use of air-conditioners decreased, electricity consumption continued to increase in 2003. The primary drivers behind this trend were the growing economy and the increase in U.S. housing stock. Use of nuclear and renewable fuels remained relatively stable. Nuclear capacity decreased slightly, and for the first time since 1997. Use of renewable fuels rose slightly due to increases in the use of hydroelectric power and biofuels.

From 2003 to 2004, these emissions increased at a rate slightly higher than the average growth rate since 1990. A number of factors played a major role in the magnitude of this increase. A primary reason behind this trend was strong growth in the U.S. economy and industrial production, particularly in energy-intensive industries, causing an increase in the demand for electricity and fossil fuels. Demand for travel was also higher, causing an increase in petroleum consumed for transportation. In contrast, the warmer winter conditions led to decreases in demand for heating fuels, principally natural gas, in both the residential and commercial sectors. Moreover, much of the increased electricity demanded was generated by natural gas consumption and nuclear power, which moderated the increase in $CO_2$ emissions from electricity generation. Use of renewable fuels rose very slightly due to increases in the use biofuels.

Other significant trends in emissions from additional source categories over the fourteen-year period from 1990 through 2004 included the following:

- $CO_2$ emissions from waste combustion increased by 8.4 Tg $CO_2$ Eq. (77 percent), as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.
- Net $CO_2$ sequestration from land use change and forestry decreased by 130.3 Tg $CO_2$ Eq. (14 percent), primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks. This decline largely resulted from a decrease in the estimated rate of forest soil sequestration caused by a slowing rate of increase in forest area after 1997.
- Methane ($CH_4$) emissions from coal mining declined by 25.6 Tg $CO_2$ Eq. (31 percent) from 1990 to 2004, as a result of the mining of less gassy coal from underground mines and the increased use of $CH_4$ collected from degasification systems.
- From 1990 to 2004, nitrous oxide ($N_2O$) emissions from mobile combustion decreased by 1 percent. However, from 1990 to 1998 emissions increased by 26 percent, due to control technologies that reduced $CH_4$ emissions while increasing $N_2O$ emissions. Since 1998, new control technologies have led to a steady decline in $N_2O$ from this source.
- Emissions resulting from the substitution of ozone depleting substances (ODS, e.g., chlorofluorocarbons [CFCs]) have increased dramatically from small amounts in 1990 to 102.9 Tg $CO_2$ Eq. in 2004. These emissions have been increasing as phase-outs of ODS required under the Montreal Protocol come into effect.
- The increase in ODS emissions is offset substantially by decreases in emission of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$) from other sources. Emissions from aluminum production decreased by 85 percent (15.6 Tg $CO_2$ Eq.) from 1990 to 2004, due to both industry emission reduction efforts and lower domestic aluminum production. Emissions from the production of HCFC-22 decreased by 55 percent (19.4 Tg $CO_2$ Eq.) from 1990 to 2004, due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23 emissions. Emissions from electric power transmission and distribution systems decreased by 52 percent (14.8 Tg $CO_2$ Eq.) from 1990 to 2004, primarily because of higher purchase prices for $SF_6$ and efforts by industry to reduce emissions.

Overall, from 1990 to 2004, total emissions of $CO_2$ increased by 982.7 Tg $CO_2$ Eq. (20 percent), while $CH_4$ and $N_2O$ emissions decreased by 61.3 Tg $CO_2$ Eq. (10 percent) and 8.2 Tg $CO_2$ Eq. (2 percent), respectively. During the same period, aggregate weighted emissions of HFCs, PFCs, and $SF_6$ rose by 52.2 Tg $CO_2$ Eq. (58 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and $SF_6$ are significant because many of them have extremely high global warming potentials and, in the cases of PFCs and $SF_6$, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and landfilled yard trimmings, which was estimated to be 11 percent of total emissions in 2004.

[BEGIN BOX]

Box 2-1: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: 1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; 2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; 3) emissions per unit of electricity consumption, because the electric power industry—utilities and nonutilities combined—was the largest source of U.S. greenhouse gas emissions in 2004; 4) emissions per unit of total gross domestic product as a measure of national economic activity; or 5) emissions per capita.

Table 2-2 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 1.1 percent since 1990. This rate is slower than that for total energy or fossil fuel consumption and much slower than that for either electricity consumption or overall gross domestic product. Total U.S. greenhouse gas emissions have also grown more slowly than national population since 1990 (see Figure 2-4). Overall, global atmospheric $CO_2$ concentrations—a function of many complex anthropogenic and natural processes—are increasing at 0.4 percent per year.

Table 2-2: Recent Trends in Various U.S. Data (Index 1990 = 100) and Global Atmospheric $CO_2$ Concentration

| **Variable** | **1991** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **Growth Rate**[f] |
|---|---|---|---|---|---|---|---|---|---|
| Greenhouse Gas Emissions[a] | 99 | 111 | 111 | 114 | 112 | 113 | 114 | 116 | 1.1% |
| Energy Consumption[b] | 100 | 112 | 114 | 117 | 114 | 116 | 116 | 118 | 1.2% |
| Fossil Fuel Consumption[b] | 99 | 113 | 114 | 117 | 115 | 116 | 117 | 118 | 1.2% |
| Electricity Consumption[b] | 102 | 121 | 123 | 127 | 125 | 128 | 129 | 131 | 2.0% |
| GDP[c] | 100 | 127 | 133 | 138 | 139 | 141 | 145 | 151 | 3.0% |
| Population[d] | 101 | 110 | 112 | 113 | 114 | 115 | 116 | 117 | 1.1% |
| Atmospheric $CO_2$ Concentration[e] | 100 | 103 | 104 | 104 | 105 | 105 | 106 | 106 | 0.4% |

[a] GWP weighted values
[b] Energy content weighted values (EIA 2004a)
[c] Gross Domestic Product in chained 2000 dollars (BEA 2005)
[d] (U.S. Census Bureau 2005)
[e] Hofmann (2004)
[f] Average annual growth rate

Figure 2-4: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product
Source: BEA (2005), U.S. Census Bureau (2005), and emission estimates in this report.

[END BOX]

As an alternative, emissions of all gases can be totaled for each of the Intergovernmental Panel on Climate Change (IPCC) sectors. Over the fourteen year period of 1990 to 2004, total emissions in the Energy, Industrial Processes, Agriculture, and Solvent and Other Product Use sectors climbed by 959.9 Tg $CO_2$ Eq. (19 percent), 19.5 Tg $CO_2$ Eq. (6 percent), 0.6 Tg $CO_2$ Eq. (less than 1 percent), and 0.5 Tg $CO_2$ Eq. (11 percent), respectively, while emissions from the Waste sector decreased 16.2 Tg $CO_2$ Eq. (8 percent). Over the same period, estimates of net carbon sequestration in the Land Use, Land-Use Change, and Forestry sector declined by 130.3 Tg $CO_2$ Eq. (14 percent).

Table 2-3 summarizes emissions and sinks from all U.S. anthropogenic sources in weighted units of Tg $CO_2$ Eq., while unweighted gas emissions and sinks in gigagrams (Gg) are provided in Figure 2-4. Alternatively, emissions and sinks are aggregated by sector/chapter in Table 2-5 and Figure 2-5.

Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg $CO_2$ Eq.)

| **Gas/Source** | **1990** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **5,005.3** | **5,620.2** | **5,695.0** | **5,864.5** | **5,795.2** | **5,815.9** | **5,877.7** | **5,988.0** |
| Fossil Fuel Combustion | 4,696.6 | 5,271.8 | 5,342.4 | 5,533.7 | 5,486.9 | 5,501.8 | 5,571.1 | 5,656.6 |
| Non-Energy Use of Fuels | 117.2 | 152.8 | 160.6 | 140.7 | 131.0 | 136.5 | 133.5 | 153.4 |
| Iron and Steel Production | 85.0 | 67.7 | 63.8 | 65.3 | 57.8 | 54.6 | 53.3 | 51.3 |
| Cement Manufacture | 33.3 | 39.2 | 40.0 | 41.2 | 41.4 | 42.9 | 43.1 | 45.6 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Waste Combustion | 10.9 | 17.1 | 17.6 | 17.9 | 18.6 | 18.9 | 19.4 | 19.4 |
| Ammonia Production and Urea Application | 19.3 | 21.9 | 20.6 | 19.6 | 16.7 | 18.5 | 15.3 | 16.9 |
| Lime Manufacture | 11.2 | 13.9 | 13.5 | 13.3 | 12.8 | 12.3 | 13.0 | 13.7 |
| Limestone and Dolomite Use | 5.5 | 7.4 | 8.1 | 6.0 | 5.7 | 5.9 | 4.7 | 6.7 |
| Natural Gas Flaring | 5.8 | 6.6 | 6.9 | 5.8 | 6.1 | 6.2 | 6.1 | 6.0 |
| Aluminum Production | 7.0 | 6.4 | 6.5 | 6.2 | 4.5 | 4.6 | 4.6 | 4.3 |
| Soda Ash Manufacture and Consumption | 4.1 | 4.3 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 |
| Petrochemical Production | 2.2 | 3.0 | 3.1 | 3.0 | 2.8 | 2.9 | 2.8 | 2.9 |
| Titanium Dioxide Production | 1.3 | 1.8 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.3 |
| Phosphoric Acid Production | 1.5 | 1.6 | 1.5 | 1.4 | 1.3 | 1.3 | 1.4 | 1.4 |
| Ferroalloys | 2.0 | 2.0 | 2.0 | 1.7 | 1.3 | 1.2 | 1.2 | 1.3 |
| $CO_2$ Consumption | 0.9 | 0.9 | 0.8 | 1.0 | 0.8 | 1.0 | 1.3 | 1.2 |
| Zinc Production | 0.9 | 1.1 | 1.1 | 1.1 | 1.0 | 0.9 | 0.5 | 0.5 |
| Lead Production | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Silicon Carbide Consumption | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| *Net $CO_2$ flux from Land Use, Land-Use Change, and Forestry*[a] | *(910.4)* | (744.0) | (765.7) | (759.5) | (768.0) | (768.6) | (774.8) | (780.1) |
| *International Bunker Fuels*[b] | *113.5* | *114.6* | *105.2* | *101.4* | *97.8* | *89.5* | *84.1* | *94.5* |
| *Biomass Combustion*[b] | *216.7* | *217.2* | *222.3* | *226.8* | *200.5* | *194.4* | *202.1* | *211.2* |
| **$CH_4$** | **618.1** | **579.5** | **569.0** | **566.9** | **560.3** | **559.8** | **564.4** | **556.7** |
| Landfills | 172.3 | 144.4 | 141.6 | 139.0 | 136.2 | 139.8 | 142.4 | 140.9 |
| Natural Gas Systems | 126.7 | 125.4 | 121.7 | 126.7 | 125.6 | 125.4 | 124.7 | 118.8 |
| Enteric Fermentation | 117.9 | 116.7 | 116.8 | 115.6 | 114.6 | 114.7 | 115.1 | 112.6 |
| Coal Mining | 81.9 | 62.8 | 58.9 | 56.3 | 55.5 | 52.5 | 54.8 | 56.3 |
| Manure Management | 31.2 | 38.8 | 38.1 | 38.0 | 38.9 | 39.3 | 39.2 | 39.4 |
| Wastewater Treatment | 24.8 | 32.6 | 33.6 | 34.3 | 34.7 | 35.8 | 36.6 | 36.9 |
| Petroleum Systems | 34.4 | 29.7 | 28.5 | 27.8 | 27.4 | 26.8 | 25.9 | 25.7 |
| Rice Cultivation | 7.1 | 7.9 | 8.3 | 7.5 | 7.6 | 6.8 | 6.9 | 7.6 |
| Stationary Sources | 7.9 | 6.8 | 7.0 | 7.3 | 6.6 | 6.2 | 6.5 | 6.4 |
| Abandoned Coal Mines | 6.0 | 6.9 | 6.9 | 7.2 | 6.6 | 6.0 | 5.8 | 5.6 |
| Mobile Sources | 4.7 | 3.8 | 3.6 | 3.5 | 3.3 | 3.2 | 3.0 | 2.9 |
| Petrochemical Production | 1.2 | 1.7 | 1.7 | 1.7 | 1.4 | 1.5 | 1.5 | 1.6 |
| Iron and Steel Production | 1.3 | 1.2 | 1.2 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 |
| Agricultural Residue Burning | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.8 | 0.9 |
| Silicon Carbide Production | + | + | + | + | + | + | + | + |
| *International Bunker Fuels*[b] | *0.2* | *0.2* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* |
| **$N_2O$** | **394.9** | **440.6** | **419.4** | **416.2** | **412.8** | **407.4** | **386.1** | **386.7** |
| Agricultural Soil Management | 266.1 | 301.1 | 281.2 | 278.2 | 282.9 | 277.8 | 259.2 | 261.5 |
| Mobile Sources | 43.5 | 54.8 | 54.1 | 53.1 | 50.0 | 47.5 | 44.8 | 42.8 |
| Manure Management | 16.3 | 17.4 | 17.4 | 17.8 | 18.1 | 18.0 | 17.5 | 17.7 |
| Nitric Acid | 17.8 | 20.9 | 20.1 | 19.6 | 15.9 | 17.2 | 16.7 | 16.6 |
| Human Sewage | 12.9 | 14.9 | 15.4 | 15.5 | 15.6 | 15.6 | 15.8 | 16.0 |
| Stationary Sources | 12.3 | 13.4 | 13.4 | 13.9 | 13.5 | 13.2 | 13.6 | 13.7 |
| Settlements Remaining Settlements | 5.6 | 6.2 | 6.2 | 6.0 | 5.8 | 6.0 | 6.2 | 6.4 |
| Adipic Acid | 15.2 | 6.0 | 5.5 | 6.0 | 4.9 | 5.9 | 6.2 | 5.7 |
| $N_2O$ Product Usage | 4.3 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 |
| Waste Combustion | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 |
| Agricultural Residue Burning | 0.4 | 0.5 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 |
| Forest Land Remaining Forest Land | 0.1 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| *International Bunker Fuels*[b] | *1.0* | *1.0* | *0.9* | *0.9* | *0.9* | *0.8* | *0.8* | *0.9* |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **HFCs, PFCs, and $SF_6$** | **90.8** | **133.4** | **131.5** | **134.7** | **124.9** | **132.7** | **131.0** | **143.0** |
| Substitution of Ozone Depleting Substances | 0.4 | 54.5 | 62.8 | 71.2 | 78.6 | 86.2 | 93.5 | 103.3 |
| HCFC-22 Production | 35.0 | 40.1 | 30.4 | 29.8 | 19.8 | 19.8 | 12.3 | 15.6 |
| Electrical Transmission and Distribution | 28.6 | 16.7 | 16.1 | 15.3 | 15.3 | 14.5 | 14.0 | 13.8 |
| Semiconductor Manufacture | 2.9 | 7.1 | 7.2 | 6.3 | 4.5 | 4.4 | 4.3 | 4.7 |
| Aluminum Production | 18.4 | 9.1 | 9.0 | 9.0 | 4.0 | 5.3 | 3.8 | 2.8 |
| Magnesium Production and Processing | 5.4 | 5.8 | 6.0 | 3.2 | 2.6 | 2.6 | 3.0 | 2.7 |
| **Total** | **6,109.0** | **6,773.7** | **6,814.9** | **6,982.3** | **6,893.1** | **6,915.8** | **6,959.1** | **7,074.4** |
| **Net Emissions (Sources and Sinks)** | **5,198.6** | **6,029.6** | **6,049.2** | **6,222.8** | **6,125.1** | **6,147.2** | **6,184.3** | **6,294.3** |

+ Does not exceed 0.05 Tg $CO_2$ Eq.
[a] The net $CO_2$ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total. Parentheses indicate negative values or sequestration.
[b] Emissions from International Bunker Fuels and Biomass Combustion are not included in totals.
Note: Totals may not sum due to independent rounding.

Table 2-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Gg)

| **Gas/Source** | **1990** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **5,005,255** | **5,620,176** | **5,695,039** | **5,864,465** | **5,795,192** | **5,815,889** | **5,877,677** | **5,987,984** |
| Fossil Fuel Combustion | 4,696,571 | 5,271,819 | 5,342,446 | 5,533,710 | 5,486,908 | 5,501,763 | 5,571,088 | 5,656,554 |
| Non-Energy Use of Fuels | 117,168 | 152,800 | 160,569 | 140,687 | 131,028 | 136,455 | 133,489 | 153,386 |
| Iron and Steel Production | 85,023 | 67,689 | 63,821 | 65,316 | 57,822 | 54,550 | 53,335 | 51,334 |
| Cement Manufacture | 33,278 | 39,218 | 39,991 | 41,190 | 41,357 | 42,898 | 43,082 | 45,559 |
| Waste Combustion | 10,919 | 17,094 | 17,632 | 17,921 | 18,634 | 18,862 | 19,360 | 19,360 |
| Ammonia Production and Urea Application | 19,306 | 21,934 | 20,615 | 19,616 | 16,719 | 18,510 | 15,278 | 16,894 |
| Lime Manufacture | 11,242 | 13,919 | 13,473 | 13,322 | 12,828 | 12,309 | 12,987 | 13,698 |
| Limestone and Dolomite Use | 5,533 | 7,449 | 8,057 | 5,960 | 5,733 | 5,885 | 4,720 | 6,702 |
| Natural Gas Flaring | 5,805 | 6,566 | 6,943 | 5,769 | 6,094 | 6,204 | 6,091 | 6,034 |
| Aluminum Production | 7,045 | 6,359 | 6,458 | 6,244 | 4,505 | 4,596 | 4,608 | 4,346 |
| Soda Ash Manufacture and Consumption | 4,141 | 4,325 | 4,217 | 4,181 | 4,147 | 4,139 | 4,111 | 4,205 |
| Petrochemical Production | 2,221 | 3,015 | 3,054 | 3,004 | 2,787 | 2,857 | 2,777 | 2,895 |
| Titanium Dioxide Production | 1,308 | 1,819 | 1,853 | 1,918 | 1,857 | 1,997 | 2,013 | 2,259 |
| Phosphoric Acid Production | 1,529 | 1,593 | 1,539 | 1,382 | 1,264 | 1,338 | 1,382 | 1,395 |
| Ferroalloys | 1,980 | 2,027 | 1,996 | 1,719 | 1,329 | 1,237 | 1,159 | 1,287 |
| $CO_2$ Consumption | 860 | 912 | 849 | 957 | 818 | 968 | 1,293 | 1,183 |
| Zinc Production | 939 | 1,140 | 1,080 | 1,129 | 976 | 927 | 502 | 502 |
| Lead Production | 285 | 308 | 310 | 311 | 293 | 290 | 289 | 259 |
| Silicon Carbide Consumption | 100 | 190 | 137 | 130 | 94 | 105 | 111 | 133 |
| *Net $CO_2$ Flux from Land Use, Land-Use Change, and Forestry*[a] | (910,373) | (744,042) | (765,692) | (759,507) | (767,987) | (768,639) | (774,848) | (780,094) |
| *International Bunker Fuels*[b] | *113,503* | *114,557* | *105,228* | *101,366* | *97,815* | *89,489* | *84,083* | *94,499* |
| *Biomass Combustion*[b] | *216,702* | *217,201* | *222,340* | *226,765* | *200,479* | *194,351* | *202,111* | *211,230* |
| **$CH_4$** | **29,432** | **27,594** | **27,094** | **26,997** | **26,679** | **26,657** | **26,875** | **26,511** |
| Landfills | 8,206 | 6,874 | 6,743 | 6,619 | 6,484 | 6,659 | 6,782 | 6,709 |
| Natural Gas Systems | 6,034 | 5,973 | 5,797 | 6,033 | 5,981 | 5,971 | 5,939 | 5,658 |
| Enteric Fermentation | 5,612 | 5,559 | 5,563 | 5,507 | 5,459 | 5,463 | 5,481 | 5,362 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Coal Mining | 3,900 | | 2,990 | 2,807 | 2,679 | 2,644 | 2,500 | 2,611 | 2,682 |
| Manure Management | 1,484 | | 1,848 | 1,816 | 1,811 | 1,850 | 1,871 | 1,865 | 1,875 |
| Wastewater Treatment | 1,180 | | 1,550 | 1,602 | 1,635 | 1,651 | 1,705 | 1,742 | 1,758 |
| Petroleum Systems | 1,640 | | 1,414 | 1,358 | 1,325 | 1,303 | 1,274 | 1,236 | 1,222 |
| Rice Cultivation | 339 | | 376 | 395 | 357 | 364 | 325 | 328 | 360 |
| Stationary Sources | 374 | | 325 | 335 | 346 | 316 | 295 | 311 | 307 |
| Abandoned Coal Mines | 286 | | 328 | 330 | 343 | 313 | 288 | 277 | 269 |
| Mobile Sources | 224 | | 181 | 173 | 167 | 159 | 152 | 144 | 140 |
| Petrochemical Production | 56 | | 80 | 81 | 80 | 68 | 72 | 72 | 77 |
| Iron and Steel Production | 63 | | 57 | 56 | 57 | 51 | 48 | 49 | 50 |
| Field Burning of Agricultural Residues | 33 | | 38 | 37 | 38 | 37 | 34 | 38 | 42 |
| Silicon Carbide Production | 1 | | 1 | 1 | 1 | + | + | + | + |
| *International Bunker Fuels[b]* | *8* | | *7* | *6* | *6* | *5* | *4* | *4* | *5* |
| **$N_2O$** | **1,274** | | **1,421** | **1,353** | **1,343** | **1,332** | **1,314** | **1,245** | **1,247** |
| Agricultural Soil Management | 858 | | 971 | 907 | 897 | 913 | 896 | 836 | 844 |
| Mobile Sources | 140 | | 177 | 174 | 171 | 161 | 153 | 144 | 138 |
| Manure Management | 52 | | 56 | 56 | 58 | 58 | 58 | 57 | 57 |
| Nitric Acid | 58 | | 67 | 65 | 63 | 51 | 56 | 54 | 54 |
| Human Sewage | 42 | | 48 | 50 | 50 | 50 | 50 | 51 | 52 |
| Stationary Sources | 40 | | 43 | 43 | 45 | 44 | 43 | 44 | 44 |
| Settlements Remaining Settlements | 18 | | 20 | 20 | 19 | 19 | 19 | 20 | 21 |
| Adipic Acid | 49 | | 19 | 18 | 19 | 16 | 19 | 20 | 19 |
| $N_2O$ Product Usage | 14 | | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Waste Combustion | 2 | | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Field Burning of Agricultural Residues | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Forest Land Remaining Forest Land | + | | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| *International Bunker Fuels[b]* | *3* | | *3* | *3* | *3* | *3* | *3* | *2* | *3* |
| **HFCs, PFCs, and $SF_6$** | **M** | | **M** | **M** | **M** | **M** | **M** | **M** | **M** |
| Substitution of Ozone Depleting Substances | M | | M | M | M | M | M | M | M |
| HCFC-22 Production | 3 | | 3 | 3 | 3 | 2 | 2 | 1 | 1 |
| Electrical Transmission and Distribution | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Semiconductor Manufacture | M | | M | M | M | M | M | M | M |
| Aluminum Production | M | | M | M | M | M | M | M | M |
| Magnesium Production and Processing[d] | + | | + | + | + | + | + | + | + |
| **$SO_2$** | **20,936** | | **17,189** | **15,917** | **14,829** | **14,452** | **13,928** | **14,208** | **13,910** |
| **$NO_x$** | **22,860** | | **21,964** | **20,530** | **20,288** | **19,414** | **18,850** | **17,995** | **17,076** |
| **CO** | **130,580** | | **98,984** | **94,361** | **92,895** | **89,329** | **87,428** | **87,518** | **87,599** |
| **NMVOCs** | **20,937** | | **16,403** | **15,869** | **15,228** | **15,048** | **14,217** | **13,877** | **13,556** |

+ Does not exceed 0.5 Gg.
M Mixture of multiple gases
[a] Sinks are not included in $CO_2$ emissions total, and are based partially on projected activity data.
[b] Emissions from International Bunker Fuels and Biomass Combustion are not included in totals.
[c] HFC-23 emitted
[d] $SF_6$ emitted
Note: Totals may not sum due to independent rounding.
Note: Parentheses indicate negative values or sequestration.

Figure 2-5: U.S. Greenhouse Gas Emissions by Chapter/IPCC Sector

Table 2-5: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg $CO_2$ Eq.)

| Chapter/IPCC Sector | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| Energy | 5,148.3 | 5,752.3 | 5,822.3 | 5,994.3 | 5,931.6 | 5,944.6 | 6,009.8 | 6,108.2 |
| Industrial Processes | 301.1 | 335.1 | 327.5 | 329.6 | 300.7 | 310.9 | 304.1 | 320.7 |
| Solvent and Other Product Use | 4.3 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 |
| Agriculture | 439.6 | 483.2 | 463.1 | 458.4 | 463.4 | 457.8 | 439.1 | 440.1 |
| Land Use, Land-Use Change, and Forestry (Emissions) | 5.7 | 6.5 | 6.7 | 6.4 | 6.2 | 6.4 | 6.6 | 6.8 |
| Waste | 210.0 | 191.8 | 190.7 | 188.8 | 186.4 | 191.3 | 194.8 | 193.8 |
| **Total** | **6,109.0** | **6,773.7** | **6,814.9** | **6,982.3** | **6,893.1** | **6,915.8** | **6,959.1** | **7,074.4** |
| Net $CO_2$ Flux from Land Use, Land-Use Change, and Forestry* | (910.4) | (744.0) | (765.7) | (759.5) | (768.0) | (768.6) | (774.8) | (780.1) |
| **Net Emissions (Sources and Sinks)** | **5,198.6** | **6,029.6** | **6,049.2** | **6,222.8** | **6,125.1** | **6,147.2** | **6,184.3** | **6,294.3** |

* The net $CO_2$ flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total..

Note: Totals may not sum due to independent rounding.

Note: Parentheses indicate negative values or sequestration.

## Energy

Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. $CO_2$ emissions for the period of 1990 through 2004. In 2004, approximately 86 percent of the energy consumed in the United States was produced through the combustion of fossil fuels. The remaining 14 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure 2-6 and Figure 2-7). A discussion of specific trends related to $CO_2$ as well as other greenhouse gas emissions from energy consumption is presented below. Energy related activities are also responsible for $CH_4$ and $N_2O$ emissions (39 percent and 15 percent of total U.S. emissions of each gas, respectively). Table 2-6 presents greenhouse gas emissions from the Energy sector, by source and gas.

Figure 2-6: 2004 Energy Sector Greenhouse Gas Sources

Figure 2-7: 2004 U.S. Fossil Carbon Flows (Tg $CO_2$ Eq.)

Table 2-6: Emissions from Energy (Tg $CO_2$ Eq.)

| Gas/Source | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **4,830.5** | **5,448.3** | **5,527.6** | **5,698.1** | **5,642.7** | **5,663.3** | **5,730.0** | **5,835.3** |
| Fossil Fuel Combustion | 4,696.6 | 5,271.8 | 5,342.4 | 5,533.7 | 5,486.9 | 5,501.8 | 5,571.1 | 5,656.6 |
| Non-Energy Use of Fuels | 117.2 | 152.8 | 160.6 | 140.7 | 131.0 | 136.5 | 133.5 | 153.4 |
| Waste Combustion | 10.9 | 17.1 | 17.6 | 17.9 | 18.6 | 18.9 | 19.4 | 19.4 |
| Natural Gas Flaring | 5.8 | 6.6 | 6.9 | 5.8 | 6.1 | 6.2 | 6.1 | 6.0 |
| *Biomass-Wood** | *212.5* | *209.5* | *214.3* | *217.6* | *190.8* | *182.9* | *186.3* | *191.7* |
| *International Bunker Fuels** | *113.5* | *114.6* | *105.2* | *101.4* | *97.8* | *89.5* | *84.1* | *94.5* |
| *Biomass-Ethanol** | *4.2* | *7.7* | *8.0* | *9.2* | *9.7* | *11.5* | *15.8* | *19.5* |
| **$CH_4$** | **261.6** | **235.4** | **226.8** | **228.7** | **225.0** | **220.1** | **220.9** | **215.8** |
| Natural Gas Systems | 126.7 | 125.4 | 121.7 | 126.7 | 125.6 | 125.4 | 124.7 | 118.8 |
| Coal Mining | 81.9 | 62.8 | 58.9 | 56.3 | 55.5 | 52.5 | 54.8 | 56.3 |
| Petroleum Systems | 34.4 | 29.7 | 28.5 | 27.8 | 27.4 | 26.8 | 25.9 | 25.7 |
| Stationary Sources | 7.9 | 6.8 | 7.0 | 7.3 | 6.6 | 6.2 | 6.5 | 6.4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Abandoned Coal Mines | 6.0 | 6.9 | 6.9 | 7.2 | 6.6 | 6.0 | 5.8 | 5.6 |
| Mobile Sources | 4.7 | 3.8 | 3.6 | 3.5 | 3.3 | 3.2 | 3.0 | 2.9 |
| *International Bunker Fuels** | *0.2* | *0.2* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* |
| **$N_2O$** | **56.2** | **68.6** | **67.9** | **67.5** | **63.9** | **61.3** | **58.9** | **57.0** |
| Mobile Sources | 43.5 | 54.8 | 54.1 | 53.1 | 50.0 | 47.5 | 44.8 | 42.8 |
| Stationary Sources | 12.3 | 13.4 | 13.4 | 13.9 | 13.5 | 13.2 | 13.6 | 13.7 |
| Waste Combustion | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 |
| *International Bunker Fuels** | *1.0* | *1.0* | *0.9* | *0.9* | *0.9* | *0.8* | *0.8* | *0.9* |
| **Total** | **5,148.3** | **5,752.3** | **5,822.3** | **5,994.3** | **5,931.6** | **5,944.6** | **6,009.8** | **6,108.2** |

* These values are presented for informational purposes only and are not included in totals or are already accounted for in other source categories.
Note: Totals may not sum due to independent rounding.

### Fossil Fuel Combustion (5,656.6 Tg $CO_2$ Eq.)

As fossil fuels are combusted, the carbon stored in them is emitted almost entirely as $CO_2$. The amount of carbon in fuels per unit of energy content varies significantly by fuel type. For example, coal contains the highest amount of carbon per unit of energy, while petroleum and natural gas have about 25 percent and 45 percent less carbon than coal, respectively. From 1990 through 2004, petroleum supplied the largest share of U.S. energy demands, accounting for an average of 39 percent of total energy consumption with natural gas and coal accounting for 24 and 23 percent of total energy consumption, respectively. Petroleum was consumed primarily in the transportation end-use sector, the vast majority of coal was used by electric power generators, and natural gas was consumed largely in the industrial and residential end-use sectors.

Emissions of $CO_2$ from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 to 2004. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 14 years, and (2) significant growth in emissions from transportation activities and electricity generation. Between 1990 and 2004, $CO_2$ emissions from fossil fuel combustion increased from 4,696.6 Tg $CO_2$ Eq. to 5,656.6 Tg $CO_2$ Eq.—a 20.4 percent total increase over the fourteen-year period.

The four major end-use sectors contributing to $CO_2$ emissions from fossil fuel combustion are industrial, transportation, residential, and commercial. Electricity generation also emits $CO_2$, although these emissions are produced as they consume fossil fuel to provide electricity to one of the four end-use sectors. For the discussion below, electricity generation emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors.

Table 2-7, Figure 2-8, and Figure 2-9 summarize $CO_2$ emissions from fossil fuel combustion by end-use sector.

Table 2-7: $CO_2$ Emissions from Fossil Fuel Combustion by End-Use Sector (Tg $CO_2$ Eq.)

| End-Use Sector | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| **Transportation** | **1,464.4** | **1,663.4** | **1,725.6** | **1,770.3** | **1,757.0** | **1,802.2** | **1,805.4** | **1,860.2** |
| Combustion | 1,461.4 | 1,660.3 | 1,722.4 | 1,766.9 | 1,753.6 | 1,798.8 | 1,801.0 | 1,855.5 |
| Electricity | 3.0 | 3.1 | 3.2 | 3.4 | 3.5 | 3.4 | 4.3 | 4.7 |
| **Industrial** | **1,528.3** | **1,634.5** | **1,613.5** | **1,642.8** | **1,574.9** | **1,542.8** | **1,572.4** | **1,595.0** |
| Combustion | 851.1 | 871.9 | 849.0 | 862.6 | 861.2 | 842.1 | 844.6 | 863.5 |
| Electricity | 677.2 | 762.6 | 764.5 | 780.3 | 713.7 | 700.7 | 727.7 | 731.5 |
| **Residential** | **922.8** | **1,044.5** | **1,064.0** | **1,123.2** | **1,123.2** | **1,139.8** | **1,166.6** | **1,166.8** |
| Combustion | 338.0 | 333.5 | 352.3 | 369.9 | 361.5 | 360.0 | 378.8 | 369.6 |
| Electricity | 584.8 | 711.0 | 711.7 | 753.3 | 761.7 | 779.8 | 787.9 | 797.2 |
| **Commercial** | **753.1** | **895.9** | **904.8** | **961.6** | **983.3** | **973.9** | **978.1** | **983.1** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Combustion | 222.6 | | 217.7 | 218.6 | 229.3 | 224.9 | 224.3 | 235.8 | 226.0 |
| Electricity | 530.5 | | 678.2 | 686.2 | 732.4 | 758.4 | 749.6 | 742.2 | 757.2 |
| **U.S. Territories** | **28.0** | | **33.5** | **34.5** | **35.8** | **48.5** | **43.1** | **48.7** | **51.4** |
| **Total** | **4,696.6** | | **5,271.8** | **5,342.4** | **5,533.7** | **5,486.9** | **5,501.8** | **5,571.1** | **5,656.6** |
| **Electricity Generation** | **1,795.5** | | **2,154.9** | **2,165.6** | **2,269.3** | **2,237.3** | **2,233.5** | **2,262.2** | **2,290.6** |

Note: Totals may not sum due to independent rounding. Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector.

Figure 2-8: 2004 $CO_2$ Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure 2-9: 2004 End-Use Sector Emissions of $CO_2$ from Fossil Fuel Combustion

*Transportation End-Use Sector*. Transportation activities (excluding international bunker fuels) accounted for 33 percent of $CO_2$ emissions from fossil fuel combustion in 2004.[3] Virtually all of the energy consumed in this end-use sector came from petroleum products. Over 60 percent of the emissions resulted from gasoline consumption for personal vehicle use. The remaining emissions came from other transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft.

*Industrial End-Use Sector*. Industrial $CO_2$ emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 28 percent of $CO_2$ from fossil fuel combustion in 2004. About half of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The other half of the emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications.

*Residential and Commercial End-Use Sectors*. The residential and commercial end-use sectors accounted for 21 and 17 percent, respectively, of $CO_2$ emissions from fossil fuel combustion in 2004. Both sectors relied heavily on electricity for meeting energy demands, with 68 and 77 percent, respectively, of their emissions attributable to electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the consumption of natural gas and petroleum for heating and cooking.

*Electricity Generation*. The United States relies on electricity to meet a significant portion of its energy demands, especially for lighting, electric motors, heating, and air conditioning. Electricity generators consumed 34 percent of U.S. energy from fossil fuels and emitted 40 percent of the $CO_2$ from fossil fuel combustion in 2004. The type of fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is generated with low $CO_2$ emitting energy technologies, particularly non-fossil options such as nuclear, hydroelectric, or geothermal energy. However, electricity generators rely on coal for over half of their total energy requirements and accounted for 94 percent of all coal consumed for energy in the United States in 2004. Consequently, changes in electricity demand have a significant impact on coal consumption and associated $CO_2$ emissions.

### Non-Energy Use of Fossil Fuels (153.4 Tg $CO_2$ Eq.)

In addition to being combusted for energy, fossil fuels are also consumed for non-energy uses (NEUs). Fuels are used in the industrial and transportation end-use sectors for a variety of NEUs, including application as solvents, lubricants, and waxes, or as raw materials in the manufacture of plastics, rubber, and synthetic fibers. $CO_2$

[3] If emissions from international bunker fuels are included, the transportation end-use sector accounted for 34 percent of U.S. emissions from fossil fuel combustion in 2004.

emissions arise from non-energy uses via several pathways. Emissions may occur during the manufacture of a product, as is the case in producing plastics or rubber from fuel-derived feedstocks. Additionally, emissions may occur during the product's lifetime, such as during solvent use. Where appropriate data and methodologies are available, NEUs of fossil fuels used for industrial processes are reported in the Industrial Processes sector. Emissions in 2004 for non-energy uses of fossil fuels were 153.4 Tg $CO_2$ Eq., which constituted 3 percent of overall fossil fuel $CO_2$ emissions and 3 percent of total national $CO_2$ emissions, approximately the same proportion as in 1990.

### Waste Combustion (19.4 Tg $CO_2$ Eq.)

Combustion is used to manage about 7 to 17 percent of the municipal solid wastes generated in the United States. The burning of garbage and non-hazardous solids, referred to as municipal solid waste, as well as the burning of hazardous waste, is usually performed to recover energy from the waste materials. $CO_2$ and $N_2O$ emissions arise from the organic materials found in these wastes. The $CO_2$ emissions from municipal solid waste containing carbon of biogenic origin (e.g., paper, yard trimmings) are not accounted for in this inventory, since they are presumed to be offset by regrowth of the original living source, and are ultimately accounted for in the Land Use, Land-Use Change, and Forestry sector. Several components of municipal solid waste, such as plastics, synthetic rubber, synthetic fibers, and carbon black, are of fossil fuel origin, and are included as sources of $CO_2$ and $N_2O$ emissions. In 2004, $CO_2$ emissions from waste combustion amounted to 19.4 Tg $CO_2$ Eq., while $N_2O$ emissions amounted to 0.5 Tg $CO_2$ Eq.

### Natural Gas Flaring (6.0 Tg $CO_2$ Eq.)

The flaring of natural gas from oil wells results in the release of $CO_2$ emissions. Natural gas is flared from both on-shore and off-shore oil wells to relieve rising pressure or to dispose of small quantities of gas that are not commercially marketable. In 2004, flaring accounted for approximately 0.1 percent of U.S. $CO_2$ emissions (6.0 Tg $CO_2$ Eq.).

### Natural Gas Systems (118.8 Tg $CO_2$ Eq.)

$CH_4$ is the major component of natural gas. Fugitive emissions of $CH_4$ occur throughout the production, processing, transmission, and distribution of natural gas. Because natural gas is often found in conjunction with petroleum deposits, leakage from petroleum systems is also a source of emissions. Emissions vary greatly from facility to facility and are largely a function of operation and maintenance procedures and equipment conditions. In 2004, $CH_4$ emissions from U.S. natural gas systems accounted for approximately 21 percent of U.S. $CH_4$ emissions.

### Coal Mining (56.3 Tg $CO_2$ Eq.)

Produced millions of years ago during the formation of coal, $CH_4$ trapped within coal seams and surrounding rock strata is released when the coal is mined. The quantity of $CH_4$ released to the atmosphere during coal mining operations depends primarily upon the type of coal and the method and rate of mining.

$CH_4$ from surface mines is emitted directly to the atmosphere as the rock strata overlying the coal seam are removed. Because $CH_4$ in underground mines is explosive at concentrations of 5 to 15 percent in air, most active underground mines are required to vent this $CH_4$, typically to the atmosphere. At some mines, $CH_4$-recovery systems may supplement these ventilation systems. During 2004, coal mining activities emitted 10 percent of U.S. $CH_4$ emissions. From 1990 to 2004, emissions from this source decreased by 31 percent due to increased use of the $CH_4$ collected by mine degasification systems and a general shift toward surface mining.

### Petroleum Systems (25.7 Tg $CO_2$ Eq.)

Petroleum is often found in the same geological structures as natural gas, and the two are often retrieved together. Crude oil is saturated with many lighter hydrocarbons, including $CH_4$. When the oil is brought to the surface and processed, many of the dissolved lighter hydrocarbons (as well as water) are removed through a series of high-pressure and low-pressure separators. The remaining hydrocarbons in the oil are emitted at various points along the system. $CH_4$ emissions from the components of petroleum systems generally occur as a result of system leaks, disruptions, and routine maintenance. In 2004, emissions from petroleum systems were about 5 percent of U.S. $CH_4$ emissions.

### Mobile Combustion (45.8 Tg $CO_2$ Eq.)

Mobile combustion results in $N_2O$ and $CH_4$ emissions. $N_2O$ is a product of the reaction that occurs between nitrogen and oxygen during fuel combustion. The quantity emitted varies according to the type of fuel, technology, and pollution control device used, as well as maintenance and operating practices. For example, some types of catalytic converters installed to reduce motor vehicle pollution can promote the formation of $N_2O$. In 2004, $N_2O$ emissions from mobile combustion were 42.8 Tg $CO_2$ Eq. (11 percent of U.S. $N_2O$ emissions). From 1990 to 2004, $N_2O$ emissions from mobile combustion decreased by about 1 percent.

In 2004, $CH_4$ emissions were estimated to be 2.9 Tg $CO_2$ Eq. The combustion of gasoline in highway vehicles was responsible for the majority of the $CH_4$ emitted from mobile combustion.

### Stationary Combustion (20.1 Tg $CO_2$ Eq.)

Stationary combustion results in $N_2O$ and $CH_4$ emissions. In 2004, $N_2O$ emissions from stationary combustion accounted for 13.7 Tg $CO_2$ Eq. (4 percent of U.S. $N_2O$ emissions). From 1990 to 2004, $N_2O$ emissions from stationary combustion increased by 11 percent, due to increased fuel consumption. In 2004, $CH_4$ emissions were 6.4 Tg $CO_2$ Eq. (1 percent of U.S. $CH_4$ emissions). The majority of $CH_4$ emissions from stationary combustion resulted from the burning of wood in the residential end-use sector.

### Abandoned Coal Mines (5.6 Tg $CO_2$ Eq.)

Coal mining activities result in the emission of $CH_4$ into the atmosphere. However, the closure of a coal mine does not correspond with an immediate cessation in the release of emissions. Following an initial decline, abandoned mines can liberate $CH_4$ at a near-steady rate over an extended period of time, or, if flooded, produce gas for only a few years. In 2004, the emissions from abandoned coal mines constituted 1 percent of U.S. $CH_4$ emissions.

### $CO_2$ from Biomass Combustion (211.2 Tg $CO_2$ Eq.)

Biomass refers to organically-based carbon fuels (as opposed to fossil-based). Biomass in the form of fuel wood and wood waste was used primarily in the industrial sector, while the transportation sector was the predominant user of biomass-based fuels, such as ethanol from corn and woody crops.

Although these fuels do emit $CO_2$, in the long run the $CO_2$ emitted from biomass consumption does not increase atmospheric $CO_2$ concentrations if the biogenic carbon emitted is offset by the growth of new biomass. For example, fuel wood burned one year but re-grown the next only recycles carbon, rather than creating a net increase in total atmospheric carbon. Net carbon fluxes from changes in biogenic carbon reservoirs in wooded or croplands are accounted for in the estimates for the Land Use, Land-Use Change, and Forestry sector. As a result, $CO_2$ emissions from biomass combustion have been estimated separately from fossil fuel-based emissions and are not included in the U.S. totals. $CH_4$ emissions from biomass combustion are included in the Stationary combustion source described above.

The consumption of wood biomass in the industrial, residential, electric power, and commercial end-use sectors accounted for 64, 16, 8, and 2 percent of gross $CO_2$ emissions from biomass combustion, respectively. Ethanol consumption in the transportation end-use sector accounted for the remaining 9 percent.

### International Bunker Fuels (95.5 Tg $CO_2$ Eq.)

Greenhouse gases emitted from the combustion of fuels used for international transport activities, termed international bunker fuels under the UNFCCC, include $CO_2$, $CH_4$, and $N_2O$. Emissions from these activities are currently not included in national emission totals, but are reported separately based upon location of fuel sales. The decision to report emissions from international bunker fuels separately, instead of allocating them to a particular country, was made by the Intergovernmental Negotiating Committee in establishing the Framework Convention on

Climate Change. These decisions are reflected in the *Revised 1996 IPCC Guidelines*, in which countries are requested to report emissions from ships or aircraft that depart from their ports with fuel purchased within national boundaries and are engaged in international transport separately from national totals (IPCC/UNEP/OECD/IEA 1997).

Two transport modes are addressed under the IPCC definition of international bunker fuels: aviation and marine. Emissions from ground transport activities—by road vehicles and trains, even when crossing international borders—are allocated to the country where the fuel was loaded into the vehicle and, therefore, are not counted as bunker fuel emissions. Emissions of $CO_2$, $CH_4$, and $N_2O$ from international bunker fuel combustion were 94.5, 0.1, and 0.9 Tg $CO_2$ Eq. in 2004, respectively.

## Industrial Processes

Emissions are produced as a by-product of many non-energy-related industrial process activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as $CO_2$, $CH_4$, and $N_2O$. The processes include iron and steel production, cement manufacture, ammonia manufacture and urea application, lime manufacture, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash manufacture and use, titanium dioxide production, phosphoric acid production, ferroalloy production, $CO_2$ consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production (see Figure 2-10). Additionally, emissions from industrial processes release HFCs, PFCs and $SF_6$. Table 2-8 presents greenhouse gas emissions from Industrial Processes by source category.

Figure 2-10: 2004 Industrial Processes Chapter Greenhouse Gas Sources

Table 2-8: Emissions from Industrial Processes (Tg $CO_2$ Eq.)

| Gas/Source | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **174.8** | **171.9** | **167.5** | **166.4** | **152.5** | **152.6** | **147.6** | **152.6** |
| Iron and Steel Production | 85.0 | 67.7 | 63.8 | 65.3 | 57.8 | 54.6 | 53.3 | 51.3 |
| Cement Manufacture | 33.3 | 39.2 | 40.0 | 41.2 | 41.4 | 42.9 | 43.1 | 45.6 |
| Ammonia Manufacture & Urea Application | 19.3 | 21.9 | 20.6 | 19.6 | 16.7 | 18.5 | 15.3 | 16.9 |
| Lime Manufacture | 11.2 | 13.9 | 13.5 | 13.3 | 12.8 | 12.3 | 13.0 | 13.7 |
| Limestone and Dolomite Use | 5.5 | 7.4 | 8.1 | 6.0 | 5.7 | 5.9 | 4.7 | 6.7 |
| Aluminum Production | 7.0 | 6.4 | 6.5 | 6.2 | 4.5 | 4.6 | 4.6 | 4.3 |
| Soda Ash Manufacture and Consumption | 4.1 | 4.3 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 |
| Petrochemical Production | 2.2 | 3.0 | 3.1 | 3.0 | 2.8 | 2.9 | 2.8 | 2.9 |
| Titanium Dioxide Production | 1.3 | 1.8 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.3 |
| Phosphoric Acid Production | 1.5 | 1.6 | 1.5 | 1.4 | 1.3 | 1.3 | 1.4 | 1.4 |
| Ferroalloy Production | 2.0 | 2.0 | 2.0 | 1.7 | 1.3 | 1.2 | 1.2 | 1.3 |
| $CO_2$ Consumption | 0.9 | 0.9 | 0.8 | 1.0 | 0.8 | 1.0 | 1.3 | 1.2 |
| Zinc Production | 0.9 | 1.1 | 1.1 | 1.1 | 1.0 | 0.9 | 0.5 | 0.5 |
| Lead Production | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Silicon Carbide Consumption | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| **$CH_4$** | **2.5** | **2.9** | **2.9** | **2.9** | **2.5** | **2.5** | **2.5** | **2.7** |
| Petrochemical Production | 1.2 | 1.7 | 1.7 | 1.7 | 1.4 | 1.5 | 1.5 | 1.6 |
| Iron and Steel Production | 1.3 | 1.2 | 1.2 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 |
| Silicon Carbide Production | + | + | + | + | + | + | + | + |
| **$N_2O$** | **33.0** | **26.9** | **25.6** | **25.6** | **20.8** | **23.1** | **22.9** | **22.4** |
| Nitric Acid Production | 17.8 | 20.9 | 20.1 | 19.6 | 15.9 | 17.2 | 16.7 | 16.6 |
| Adipic Acid Production | 15.2 | 6.0 | 5.5 | 6.0 | 4.9 | 5.9 | 6.2 | 5.7 |
| **HFCs, PFCs, and $SF_6$** | **90.8** | **133.4** | **131.5** | **134.7** | **124.9** | **132.7** | **131.0** | **143.0** |
| Substitution of Ozone Depleting Substances | 0.4 | 54.5 | 62.8 | 71.2 | 78.6 | 86.2 | 93.5 | 103.3 |
| HCFC-22 Production | 35.0 | 40.1 | 30.4 | 29.8 | 19.8 | 19.8 | 12.3 | 15.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Electrical Transmission and Distribution | 28.6 | | 16.7 | 16.1 | 15.3 | 15.3 | 14.5 | 14.0 | 13.8 |
| Semiconductor Manufacture | 2.9 | | 7.1 | 7.2 | 6.3 | 4.5 | 4.4 | 4.3 | 4.7 |
| Aluminum Production | 18.4 | | 9.1 | 9.0 | 9.0 | 4.0 | 5.3 | 3.8 | 2.8 |
| Magnesium Production and Processing | 5.4 | | 5.8 | 6.0 | 3.2 | 2.6 | 2.6 | 3.0 | 2.7 |
| **Total** | **301.1** | | **335.1** | **327.5** | **329.6** | **300.7** | **310.9** | **304.1** | **320.7** |

+ Does not exceed 0.05 Tg $CO_2$ Eq.
Note: Totals may not sum due to independent rounding.

### Iron and Steel Production (52.4 Tg $CO_2$ Eq.)

Pig iron is the product of combining iron oxide (i.e., iron ore) and sinter with metallurgical coke in a blast furnace. The pig iron production process, as well as the thermal processes used to create sinter and metallurgical coke, resulted in emissions of $CO_2$ and $CH_4$. In 2004, iron and steel production resulted in 1.0 Tg $CO_2$ Eq. of $CH_4$ emissions, with the majority of the emissions coming from the pig iron production process. The majority of $CO_2$ emissions from iron and steel processes come from the production of coke for use in pig iron creation, with smaller amounts evolving from the removal of carbon from pig iron used to produce steel. $CO_2$ emissions from iron and steel amounted to 51.3 Tg $CO_2$ Eq. in 2004. From 1990 to 2004, overall emissions from this source decreased by 39 percent.

### Cement Manufacture (45.6 Tg $CO_2$ Eq.)

Clinker is an intermediate product in the formation of finished Portland and masonry cement. Heating calcium carbonate ($CaCO_3$) in a cement kiln forms lime and $CO_2$. The lime combines with other materials to produce clinker, and the $CO_2$ is released into the atmosphere. From 1990 to 2004, emissions from this source increased by 37 percent.

### Ammonia Manufacture and Urea Application (16.9 Tg $CO_2$ Eq.)

In the United States, roughly 98 percent of synthetic ammonia is produced by catalytic steam reforming of natural gas, and the remainder is produced using naphtha (i.e., a petroleum fraction) or the electrolysis of brine at chlorine plants (EPA 1997). The two fossil fuel-based reactions produce carbon monoxide and hydrogen gas. This carbon monoxide is transformed into $CO_2$ in the presence of a catalyst. The $CO_2$ is generally released into the atmosphere, but some of the $CO_2$, together with ammonia, is used as a raw material in the production of urea [$CO(NH_2)_2$], which is a type of nitrogenous fertilizer. The carbon in the urea that is produced and assumed to be subsequently applied to agricultural land as a nitrogenous fertilizer is ultimately released into the environment as $CO_2$.

### Lime Manufacture (13.7 Tg $CO_2$ Eq.)

Lime is used in steel making, construction, flue gas desulfurization, and water and sewage treatment. It is manufactured by heating limestone (mostly calcium carbonate, $CaCO_3$) in a kiln, creating quicklime (calcium oxide, CaO) and $CO_2$, which is normally emitted to the atmosphere.

### Limestone and Dolomite Use (6.7 Tg $CO_2$ Eq.)

Limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) are basic raw materials used in a wide variety of industries, including construction, agriculture, chemical, and metallurgy. For example, limestone can be used as a purifier in refining metals. In the case of iron ore, limestone heated in a blast furnace reacts with impurities in the iron ore and fuels, generating $CO_2$ as a by-product. Limestone is also used in flue gas desulfurization systems to remove sulfur dioxide from the exhaust gases.

### Aluminum Production (7.2 Tg $CO_2$ Eq.)

Aluminum production results in emissions of $CO_2$, $CF_4$ and $C_2F_6$. $CO_2$ is emitted when alumina (aluminum oxide, $Al_2O_3$) is reduced to aluminum. The reduction of the alumina occurs through electrolysis in a molten bath of natural or synthetic cryolite. The reduction cells contain a carbon lining that serves as the cathode. Carbon is also contained in the anode, which can be a carbon mass of paste, coke briquettes, or prebaked carbon blocks from petroleum coke. During reduction, some of this carbon is oxidized and released to the atmosphere as $CO_2$. In 2004, $CO_2$ emissions from aluminum production amounted to 4.3 Tg $CO_2$ Eq.

During the production of primary aluminum, $CF_4$ and $C_2F_6$ are emitted as intermittent by-products of the smelting process. These PFCs are formed when fluorine from the cryolite bath combines with carbon from the electrolyte anode. PFC emissions from aluminum production have decreased by 85 percent between 1990 and 2004 due to emission reduction efforts by the industry and falling domestic aluminum production. In 2004, $CF_4$ and $C_2F_6$ emissions from aluminum production amounted to 2.8 Tg $CO_2$ Eq.

### Soda Ash Manufacture and Consumption (4.2 Tg $CO_2$ Eq.)

Commercial soda ash (sodium carbonate, $Na_2CO_3$) is used in many consumer products, such as glass, soap and detergents, paper, textiles, and food. During the manufacturing of soda ash, some natural sources of sodium carbonate are heated and transformed into a crude soda ash, in which $CO_2$ is generated as a by-product. In addition, $CO_2$ is often released when the soda ash is consumed.

### Petrochemical Production (4.5 Tg $CO_2$ Eq.)

The production process for carbon black results in the release $CO_2$ emissions to the atmosphere. Carbon black is a black powder generated by the incomplete combustion of an aromatic petroleum or coal-based feedstock production. The majority of carbon black produced in the United States is consumed by the tire industry, which adds it to rubber to increase strength and abrasion resistance. Small amounts of $CH_4$ are also released during the production of five petrochemicals: carbon black, ethylene, ethylene dichloride, styrene, and methanol. These production processes resulted in emissions of 2.9 Tg $CO_2$ Eq. of $CO_2$ and 1.6 Tg $CO_2$ Eq. of $CH_4$ in 2004.

### Titanium Dioxide Production (2.3 Tg $CO_2$ Eq.)

Titanium dioxide ($TiO_2$) is a metal oxide manufactured from titanium ore, and is principally used as a pigment. It is used in white paint and as a pigment in the manufacture of white paper, foods, and other products. Two processes, the chloride process and the sulfate process, are used for making $TiO_2$. $CO_2$ is emitted from the chloride process, which uses petroleum coke and chlorine as raw materials.

### Phosphoric Acid Production (1.4 Tg $CO_2$ Eq.)

Phosphoric acid is a basic raw material in the production of phosphate-based fertilizers. The phosphate rock consumed in the United States originates from both domestic mines, located primarily in Florida, North Carolina, Idaho, and Utah, and foreign mining operations in Morocco. The primary use of this material is as a basic component of a series of chemical reactions that lead to the production of phosphoric acid, as well as the by-products $CO_2$ and phosphogypsum.

### Ferroalloy Production (1.3 Tg $CO_2$ Eq.)

$CO_2$ is emitted from the production of several ferroalloys. Ferroalloys are composites of iron and other elements such as silicon, manganese, and chromium. When incorporated in alloy steels, ferroalloys are used to alter the material properties of the steel.

### Carbon Dioxide Consumption (1.2 Tg $CO_2$ Eq.)

Many segments of the economy consume $CO_2$, including food processing, beverage manufacturing, chemical processing, and a host of industrial and other miscellaneous applications. $CO_2$ may be produced as a by-product from the production of certain chemicals (e.g., ammonia), from select natural gas wells, or by separating it from crude oil and natural gas. The majority of the $CO_2$ used in these applications is eventually released to the atmosphere.

### Zinc Production (0.5 Tg $CO_2$ Eq.)

$CO_2$ emissions from the production of zinc in the United States occur through the primary production of zinc in the electro-thermic production process, or through the secondary production of zinc using a Waelz Kiln furnace or the electro-thermic production process. Both the electro-thermic and Waelz Kiln processes are emissive due to the use of a carbon-based material (often metallurgical coke); however, zinc is also produced in the United States using non-emissive processes. Due to the closure of an electro-thermic plant in 2003, the only emissive zinc production process remaining occurs through the recycling of electric-arc-furnace (EAF) dust in a Waelz Kiln furnace (secondary production) at a plant in Palmerton, Pennsylvania.

### Lead Production (0.3 Tg $CO_2$ Eq.)

Primary and secondary production of lead in the United States results in $CO_2$ emissions when carbon-based materials (often metallurgical coke) are used as a reducing agent. Primary production involves the direct smelting of lead concentrates while secondary production largely occurs through the recycling of lead-acid batteries. In 2004, emissions from primary lead production decreased by 40 percent due to the closure of one of two primary lead production plants located in Missouri. Secondary lead production accounted for 85 percent of total lead production emissions in 2004.

### Silicon Carbide Production and Consumption (0.1 Tg $CO_2$ Eq.)

Small amounts of $CH_4$ are released during the production of silicon carbide (SiC), a material used as an industrial abrasive. Additionally, small amounts of $CO_2$ are released when SiC is consumed for metallurgical and other non-abrasive purposes (e.g., iron and steel production). Silicon carbide is made through a reaction of quartz ($SiO_2$) and carbon (in the form of petroleum coke). $CH_4$ is produced during this reaction from volatile compounds in the petroleum coke. $CH_4$ emissions from silicon carbide production have declined significantly due to a 67 percent decrease in silicon carbide production since 1990. $CO_2$ emissions from SiC consumption have fluctuated significantly between years dependent on consumption, but overall have increased by 33 percent since 1990.

### Nitric Acid Production (16.6 Tg $CO_2$ Eq.)

Nitric acid production is an industrial source of $N_2O$ emissions. Used primarily to make synthetic commercial fertilizer, this raw material is also a major component in the production of adipic acid and explosives.

Virtually all of the nitric acid manufactured in the United States is produced by the oxidation of ammonia, during which $N_2O$ is formed and emitted to the atmosphere. In 2004, $N_2O$ emissions from nitric acid production accounted for 4 percent of U.S. $N_2O$ emissions. From 1990 to 2004, emissions from this source category decreased by 7 percent with the trend in the time series closely tracking the changes in production.

### Adipic Acid Production (5.7 Tg $CO_2$ Eq.)

Most adipic acid produced in the United States is used to manufacture nylon 6,6. Adipic acid is also used to produce some low-temperature lubricants and to add a "tangy" flavor to foods. $N_2O$ is emitted as a by-product of the chemical synthesis of adipic acid.

In 2004, U.S. adipic acid plants emitted 1.5 percent of U.S. $N_2O$ emissions. Even though adipic acid production has increased in recent years, by 1998 all three major adipic acid plants in the United States had voluntarily implemented $N_2O$ abatement technology. As a result, emissions have decreased by 62 percent since 1990.

### Substitution of Ozone Depleting Substances (103.3 Tg $CO_2$ Eq.)

The use and subsequent emissions of HFCs and PFCs as substitutes for ODSs have increased from small amounts in 1990 to account for 72 percent of aggregate HFC, PFC, and $SF_6$ emissions. This increase was in large part the result of efforts to phase-out CFCs and other ODSs in the United States, especially the introduction of HFC-134a as a CFC substitute in refrigeration and air-conditioning applications. In the short term, this trend is expected to continue, and will likely accelerate over the coming decade as HCFCs, which are interim substitutes in many applications, are themselves phased-out under the provisions of the Copenhagen Amendments to the *Montreal Protocol*. Improvements in the technologies associated with the use of these gases and the introduction of alternative gases and technologies, however, may help to offset this anticipated increase in emissions.

### HCFC-22 Production (15.6 Tg $CO_2$ Eq.)

HFC-23 is a by-product of the production of HCFC-22. Emissions from this source have decreased by 55 percent since 1990. The HFC-23 emission rate (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) has declined significantly since 1990, although production has been increasing.

### Electrical Transmission and Distribution Systems (13.8 Tg $CO_2$ Eq.)

The primary use of $SF_6$ is as a dielectric in electrical transmission and distribution systems. Fugitive emissions of $SF_6$ occur from leaks in and servicing of substations and circuit breakers, especially from older equipment. The gas can also be released during equipment manufacturing, installation, servicing, and disposal. Estimated emissions from this source decreased by 52 percent since 1990, primarily due to higher $SF_6$ prices and industrial efforts to reduce emissions.

### Semiconductor Manufacture (4.7 Tg $CO_2$ Eq.)

The semiconductor industry uses combinations of HFCs, PFCs, $SF_6$, and other gases for plasma etching and to clean chemical vapor deposition tools. Emissions from this source category have increased 62 percent since 1990 with the growth in the semiconductor industry and the rising intricacy of chip designs. However, the growth rate in emissions has slowed since 1997, and emissions actually declined between 1999 and 2004. This later reduction is due to the implementation of PFC emission reduction methods, such as process optimization.

### Magnesium Production (2.7 Tg $CO_2$ Eq.)

Sulfur hexafluoride is also used as a protective cover gas for the casting of molten magnesium. Emissions from primary magnesium production and magnesium casting have decreased by 50 percent since 1990. This decrease has primarily taken place since 1999, due to a decline in the quantity of magnesium die cast and the closure of a U.S. primary magnesium production facility.

## Solvent and Other Product Use

Greenhouse gas emissions are produced as a by-product of various solvent and other product uses. In the United States, emissions from $N_2O$ Product Usage, the only source of greenhouse gas emissions from this sector, accounted for 4.8 Tg $CO_2$ Eq. of $N_2O$, or less than 0.1 percent of total U.S. emissions in 2004 (see Table 2-9).

Table 2-9: $N_2O$ Emissions from Solvent and Other Product Use (Tg $CO_2$ Eq.)

| Gas/Source | 1990 | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **$N_2O$** | **4.3** | | **4.8** | **4.8** | **4.8** | **4.8** | **4.8** | **4.8** | **4.8** |
| $N_2O$ Product Usage | 4.3 | | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 |
| **Total** | **4.3** | | **4.8** | **4.8** | **4.8** | **4.8** | **4.8** | **4.8** | **4.8** |

### $N_2O$ Product Usage (4.8 Tg $CO_2$ Eq.)

$N_2O$ is used in carrier gases with oxygen to administer more potent inhalation anesthetics for general anesthesia and as an anesthetic in various dental and veterinary applications. As such, it is used to treat short-term pain, for sedation in minor elective surgeries and as an induction anesthetic. The second main use of $N_2O$ is as a propellant in pressure and aerosol products, the largest application being pressure-packaged whipped cream. In 2004, $N_2O$ emissions from product usage constituted approximately 1 percent of U.S. $N_2O$ emissions. From 1990 to 2004, emissions from this source category increased by 11 percent.

## Agriculture

Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues.

In 2004, agricultural activities were responsible for emissions of 440.1 Tg $CO_2$ Eq., or 6.2 percent of total U.S. greenhouse gas emissions. $CH_4$ and $N_2O$ were the primary greenhouse gases emitted by agricultural activities. $CH_4$ emissions from enteric fermentation and manure management represented about 20 percent and 7 percent of total $CH_4$ emissions from anthropogenic activities, respectively in 2004. Agricultural soil management activities such as fertilizer application and other cropping practices were the largest source of U.S. $N_2O$ emissions in 2004, accounting for 68 percent. Table 2-10 presents emission estimates for the Agriculture sector.

Figure 2-11: 2004 Agriculture Chapter Greenhouse Gas Sources

Table 2-10: Emissions from Agriculture (Tg $CO_2$ Eq.)

| Gas/Source | 1990 | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **$CH_4$** | **156.8** | | **164.2** | **164.0** | **162.0** | **161.9** | **161.5** | **161.8** | **160.4** |
| Enteric Fermentation | 117.9 | | 116.7 | 116.8 | 115.6 | 114.5 | 114.7 | 115.1 | 112.6 |
| Manure Management | 31.2 | | 38.8 | 38.1 | 38.0 | 38.9 | 39.3 | 39.2 | 39.4 |
| Rice Cultivation | 7.1 | | 7.9 | 8.3 | 7.5 | 7.6 | 6.8 | 6.9 | 7.6 |
| Field Burning of Agricultural Residues | 0.7 | | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.8 | 0.9 |
| **$N_2O$** | **282.7** | | **319.0** | **299.1** | **296.5** | **301.5** | **296.2** | **277.1** | **279.7** |
| Agricultural Soil Management | 266.1 | | 301.1 | 281.2 | 278.2 | 282.9 | 277.8 | 259.2 | 261.5 |
| Manure Management | 16.3 | | 17.4 | 17.4 | 17.8 | 18.1 | 18.0 | 17.5 | 17.7 |
| Field Burning of Agricultural Residues | 0.4 | | 0.5 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 |
| **Total** | **439.6** | | **483.2** | **463.1** | **458.4** | **463.4** | **457.8** | **439.1** | **440.1** |

Note: Totals may not sum due to independent rounding.

### Enteric Fermentation (112.6 Tg $CO_2$ Eq.)

During animal digestion, $CH_4$ is produced through the process of enteric fermentation, in which microbes residing in animal digestive systems break down food. Ruminants, which include cattle, buffalo, sheep, and goats, have the highest $CH_4$ emissions among all animal types because they have a rumen, or large fore-stomach, in which $CH_4$-producing fermentation occurs. Non-ruminant domestic animals, such as pigs and horses, have much lower $CH_4$ emissions. In 2004, enteric fermentation was the source of about 20 percent of U.S. $CH_4$ emissions, and more than 70 percent of the $CH_4$ emissions from agriculture. From 1990 to 2004, emissions from this source decreased by 4 percent. Generally, emissions have been decreasing since 1995, mainly due to decreasing populations of both beef and dairy cattle and improved feed quality for feedlot cattle.

### Manure Management (57.1 Tg $CO_2$ Eq.)

Both $CH_4$ and $N_2O$ result from manure management. The decomposition of organic animal waste in an anaerobic environment produces $CH_4$. The most important factor affecting the amount of $CH_4$ produced is how the manure is managed, because certain types of storage and treatment systems promote an oxygen-free environment. In particular, liquid systems tend to encourage anaerobic conditions and produce significant quantities of $CH_4$, whereas solid waste management approaches produce little or no $CH_4$. Higher temperatures and moist climatic conditions also promote $CH_4$ production.

Emissions from manure management were 39.4 Tg $CO_2$ Eq., or about 7 percent of U.S. $CH_4$ emissions in 2004 and 25 percent of the $CH_4$ emissions from the agriculture sector. From 1990 to 2004, emissions from this source increased by 26 percent. The bulk of this increase was from swine and dairy cow manure, and is attributed to the shift in the composition of the swine and dairy industries towards larger facilities. Larger swine and dairy farms tend to use liquid management systems.

$N_2O$ is also produced as part of microbial nitrification and denitrification processes in managed and unmanaged manure. Emissions from unmanaged manure are accounted for within the agricultural soil management source category. Total $N_2O$ emissions from managed manure systems in 2004 accounted for 17.7 Tg $CO_2$ Eq., or 5 percent of U.S. $N_2O$ emissions. From 1990 to 2004, emissions from this source category increased by 9 percent, primarily due to increases in swine and poultry populations over the same period.

### Rice Cultivation (7.6 Tg $CO_2$ Eq.)

Most of the world's rice, and all of the rice in the United States, is grown on flooded fields. When fields are flooded, anaerobic conditions develop and the organic matter in the soil decomposes, releasing $CH_4$ to the atmosphere, primarily through the rice plants. In 2004, rice cultivation was the source of 1 percent of U.S. $CH_4$ emissions, and about 5 percent of U.S. $CH_4$ emissions from agriculture. Emission estimates from this source have increased about 6 percent since 1990.

### Field Burning of Agricultural Residues (1.4 Tg $CO_2$ Eq.)

Burning crop residue releases $N_2O$ and $CH_4$. Because field burning is not a common debris clearing method used in the United States, it was responsible for only 0.2 percent of U.S. $CH_4$ (0.9 Tg $CO_2$ Eq.) and 0.1 percent of U.S. $N_2O$ (0.5 Tg $CO_2$ Eq.) emissions in 2004.

### Agricultural Soil Management (261.5 Tg $CO_2$ Eq.)

$N_2O$ is produced naturally in soils through microbial nitrification and denitrification processes. A number of anthropogenic activities add to the amount of nitrogen available to be emitted as $N_2O$ by microbial processes. These activities may add nitrogen to soils either directly or indirectly. Direct additions occur through the application of synthetic and organic fertilizers; production of nitrogen-fixing crops and forages; the application of livestock manure, crop residues, and sewage sludge; cultivation of high-organic-content soils; and direct excretion by animals onto soil. Indirect additions result from volatilization and subsequent atmospheric deposition, and from leaching and surface run-off of some of the nitrogen applied to or deposited on soils as fertilizer, livestock manure, and sewage sludge.

In 2004, agricultural soil management accounted for 68 percent of U.S. $N_2O$ emissions. From 1990 to 2004, emissions from this source decreased slightly as fertilizer consumption, manure production, and production of nitrogen-fixing and other crops rose. Year-to-year fluctuations are largely a reflection of annual variations in climate, synthetic fertilizer consumption, and crop production.

## Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also alter the background carbon fluxes between biomass, soils, and the atmosphere. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps have resulted in a net uptake (sequestration) of carbon in the United States, which offset about 11 percent of total U.S. greenhouse gas emissions in 2004. Forests (including vegetation, soils, and harvested wood) accounted for approximately 82 percent of total 2004 sequestration, urban trees accounted for 11 percent, agricultural soils (including mineral and organic soils and the application of lime) accounted for 6 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total sequestration in 2004. The net forest sequestration is a result of net forest growth and increasing forest area, as well as a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth in these areas. In agricultural soils, mineral soils account for a net carbon sink that is almost two times larger than the sum of emissions from organic soils and liming. The mineral soil carbon sequestration is largely due to conversion of cropland to permanent pastures and hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and sewage sludge) applied to agriculture lands. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard trimming carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2004 resulted in a net carbon sequestration of 780.1 Tg $CO_2$ Eq. (Table 2-11). This represents an offset of approximately 13 percent of total U.S. $CO_2$ emissions. Total land use, land-use change, and forestry net carbon sequestration declined by approximately 14 percent between 1990 and 2004, which contributed to an increase in net U.S. emissions (all sources and sinks) of 21 percent from 1990 to 2004. This decline was primarily due to a decline in the rate of net carbon accumulation in forest carbon stocks. Annual carbon accumulation in landfilled yard trimmings and food scraps and agricultural soils also slowed over this period, while the rate of carbon accumulation in agricultural soils and urban trees increased.

Table 2-11: Net $CO_2$ Flux from Land Use, Land-Use Change, and Forestry (Tg $CO_2$ Eq.)

| Sink Category | 1990 | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **Forest Land Remaining Forest Land** | **(773.4)** | | **(618.8)** | **(637.9)** | **(631.0)** | **(634.0)** | **(634.6)** | **(635.8)** | **(637.2)** |
| Changes in Forest Carbon Stocks | (773.4) | | (618.8) | (637.9) | (631.0) | (634.0) | (634.6) | (635.8) | (637.2) |
| **Cropland Remaining Cropland** | **(33.1)** | | **(24.6)** | **(24.6)** | **(26.1)** | **(27.8)** | **(27.5)** | **(28.7)** | **(28.9)** |
| Changes in Agricultural Soil Carbon Stocks and Liming Emissions | (33.1) | | (24.6) | (24.6) | (26.1) | (27.8) | (27.5) | (28.7) | (28.9) |
| **Land Converted to Cropland** | **1.5** | | **(2.8)** | **(2.8)** | **(2.8)** | **(2.8)** | **(2.8)** | **(2.8)** | **(2.8)** |
| Changes in Agricultural Soil Carbon Stocks | 1.5 | | (2.8) | (2.8) | (2.8) | (2.8) | (2.8) | (2.8) | (2.8) |
| **Grassland Remaining Grassland** | **(4.5)** | | **7.5** | **7.5** | **7.4** | **7.4** | **7.4** | **7.3** | **7.3** |
| Changes in Agricultural Soil Carbon Stocks | (4.5) | | 7.5 | 7.5 | 7.4 | 7.4 | 7.4 | 7.3 | 7.3 |
| **Land Converted to Grassland** | **(17.6)** | | **(21.1)** | **(21.1)** | **(21.1)** | **(21.1)** | **(21.1)** | **(21.1)** | **(21.1)** |
| Changes in Agricultural Soil Carbon Stocks | (17.6) | | (21.1) | (21.1) | (21.1) | (21.1) | (21.1) | (21.1) | (21.1) |
| **Settlements Remaining Settlements** | **(83.2)** | | **(84.2)** | **(86.8)** | **(85.9)** | **(89.7)** | **(89.9)** | **(93.8)** | **(97.3)** |
| Urban Trees | (58.7) | | (73.3) | (77.0) | (77.0) | (80.7) | (80.7) | (84.3) | (88.0) |
| Landfilled Yard Trimmings and Food Scraps | (24.5) | | (10.9) | (9.8) | (8.9) | (9.0) | (9.3) | (9.4) | (9.3) |
| **Total** | **(910.4)** | | **(744.0)** | **(765.7)** | **(759.5)** | **(768.0)** | **(768.6)** | **(774.8)** | **(780.1)** |

Note: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

Land use, land-use change, and forestry activities in 2004 also resulted in emissions of $N_2O$ (6.8 Tg $CO_2$ Eq., Table 2-12). Total $N_2O$ emissions from the application of fertilizers to forests and settlements increased by approximately 20 percent between 1990 and 2004.

Table 2-12: $N_2O$ Emissions from Land Use, Land-Use Change, and Forestry (Tg $CO_2$ Eq.)

| Sink Category | 1990 | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **Forest Land Remaining Forest Land** | **0.1** | | **0.4** | **0.5** | **0.4** | **0.4** | **0.4** | **0.4** | **0.4** |
| $N_2O$ Fluxes from Soils | 0.1 | | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| **Settlements Remaining Settlements** | **5.6** | | **6.2** | **6.2** | **6.0** | **5.8** | **6.0** | **6.2** | **6.4** |
| $N_2O$ Fluxes from Soils | 5.6 | | 6.2 | 6.2 | 6.0 | 5.8 | 6.0 | 6.2 | 6.4 |
| **Total** | **5.7** | | **6.5** | **6.7** | **6.4** | **6.2** | **6.4** | **6.6** | **6.8** |

Note: Totals may not sum due to independent rounding.

### Forest Land Remaining Forest Land (0.4 Tg $CO_2$ Eq.)

As with other agricultural applications, forests may be fertilized to stimulate growth rates. The relative magnitude of the impact of this practice is limited, however, because forests are generally only fertilized twice during their life cycles, and applications account for no more than one percent of total U.S. fertilizer applications annually. In terms of trends, however, $N_2O$ emissions from forest soils for 2004 were almost 7 times higher than in 1990, primarily the result of an increase in the fertilized area of pine plantations in the southeastern U.S. This source accounts for approximately 0.1 percent of total U.S. $N_2O$ emissions.

### Settlements Remaining Settlements (6.4 Tg $CO_2$ Eq.)

Of the fertilizers applied to soils in the United States, approximately 10 percent are applied to lawns, golf courses, and other landscaping within settled areas. In 2004, $N_2O$ emissions from settlement soils constituted approximately 1.7 percent of total U.S. $N_2O$ emissions. There has been an overall increase in emissions of 15 percent since 1990, a result of a general increase in the applications of synthetic fertilizers.

## Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-12). Landfills were the largest source of anthropogenic $CH_4$ emissions, accounting for 25 percent of total U.S. $CH_4$ emissions.[4] Additionally, wastewater treatment accounts for 7 percent of U.S. $CH_4$ emissions. $N_2O$ emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were $N_2O$ emissions from the treatment process itself, using a simplified methodology. Wastewater treatment systems are a potentially significant source of $N_2O$ emissions; however, methodologies are not currently available to develop a complete estimate. $N_2O$ emissions from the treatment of the human sewage component of wastewater were estimated, however, using a simplified methodology. Nitrogen oxide ($NO_x$), carbon monoxide (CO), and non-$CH_4$ volatile organic compounds (NMVOCs) are also emitted by waste activities. A summary of greenhouse gas emissions from the Waste sector is presented in Table 2-13.

Figure 2-12: 2004 Waste Sector Greenhouse Gas Sources

Overall, in 2004, waste activities generated emissions of 193.8 Tg $CO_2$ Eq., or 2.7 percent of total U.S. greenhouse gas emissions.

Table 2-13: Emissions from Waste (Tg $CO_2$ Eq.)

| Gas/Source | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| **$CH_4$** | **197.1** | **176.9** | **175.3** | **173.3** | **170.8** | **175.6** | **179.0** | **177.8** |
| Landfills | 172.3 | 144.4 | 141.6 | 139.0 | 136.2 | 139.8 | 142.4 | 140.9 |
| Wastewater Treatment | 24.8 | 32.6 | 33.6 | 34.3 | 34.7 | 35.8 | 36.6 | 36.9 |
| **$N_2O$** | **12.9** | **14.9** | **15.4** | **15.5** | **15.6** | **15.6** | **15.8** | **16.0** |
| Human Sewage | 12.9 | 14.9 | 15.4 | 15.5 | 15.6 | 15.6 | 15.8 | 16.0 |
| **Total** | **210.0** | **191.8** | **190.7** | **188.8** | **186.4** | **191.3** | **194.8** | **193.8** |

Note: Totals may not sum due to independent rounding.

### Landfills (140.9 Tg $CO_2$ Eq.)

Landfills are the largest anthropogenic source of $CH_4$ emissions in the United States, accounting for approximately 25 percent of total $CH_4$ emissions in 2004. In an environment where the oxygen content is low or zero, anaerobic bacteria can decompose organic materials, such as yard waste, household waste, food waste, and paper, resulting in the generation of $CH_4$ and biogenic $CO_2$. Site-specific factors, such as waste composition, moisture, and landfill size, influence the level of $CH_4$ generation.

From 1990 to 2004, net $CH_4$ emissions from landfills decreased by approximately 18 percent, with small increases occurring in some interim years. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted by landfill operators, which has more than offset the additional $CH_4$ emissions resulting from an increase in the amount of municipal solid waste landfilled.

[4] Landfills also store carbon, due to incomplete degradation of organic materials such as wood products and yard trimmings, as described in the Land-Use, Land-Use Change, and Forestry chapter.

### Wastewater Treatment (36.9 Tg $CO_2$ Eq.)

Wastewater from domestic sources (i.e., municipal sewage) and industrial sources is treated to remove soluble organic matter, suspended solids, pathogenic organisms and chemical contaminants. Soluble organic matter is generally removed using biological processes in which microorganisms consume the organic matter for maintenance and growth. Microorganisms can biodegrade soluble organic material in wastewater under aerobic or anaerobic conditions, with the latter condition producing $CH_4$. During collection and treatment, wastewater may be accidentally or deliberately managed under anaerobic conditions. In addition, the sludge may be further biodegraded under aerobic or anaerobic conditions. Untreated wastewater may also produce $CH_4$ if contained under anaerobic conditions. In 2004, wastewater treatment was the source of approximately 7 percent of U.S. $CH_4$ emissions.

### Human Sewage (Domestic Wastewater) (16.0 Tg $CO_2$ Eq.)

Domestic human sewage is usually mixed with other household wastewater, which includes drainage from showers and sinks, washing machine effluent, etc., and transported by a collection system to either a direct discharge, or an on-site, decentralized, or centralized wastewater treatment system. After processing, treated effluent may be discharged to a receiving water environment (e.g., river, lake, estuary, etc.), applied to soils, or disposed of below the surface. $N_2O$ may be generated during both nitrification and denitrification of the nitrogen present, usually in the form of urea, ammonia, and proteins. Emissions of $N_2O$ from treated human sewage discharged into aquatic environments accounted for 4 percent of U.S. $N_2O$ emissions in 2004. From 1990 to 2004, emissions from this source category increased by 24 percent.

## *2.2. Emissions by Economic Sector*

Throughout this report, emission estimates are grouped into six sectors (i.e., chapters) defined by the IPCC: Energy, Industrial Processes, Solvent Use, Agriculture, Land Use, Land-Use Change, and Forestry, and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following “economic sectors”: Residential, Commercial, Industry, Transportation, Electricity Generation, and Agriculture, as well as U.S. Territories. Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2004. Transportation activities, in aggregate, accounted for the second largest portion (28 percent). Additional discussion and data on these two economic sectors is provided below.

Emissions from industry accounted for 19 percent of U.S. greenhouse gas emissions in 2004. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade, although there was an increase in industrial emissions in 2004 (up 3 percent from 2003 levels). The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The residential, agriculture, commercial economic sectors, and U.S. territories, contributed the remaining 20 percent of emissions. The residential economic sector accounted for approximately 6 percent, and primarily consisted of $CO_2$ emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 7 percent of U.S. emissions, but unlike all other economic sectors these emissions were dominated by non-$CO_2$ emissions. The commercial sector accounted for about 7 percent of emissions, while U.S. territories accounted for 1 percent of total emissions.

$CO_2$ was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Table 2-14 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-13 shows the trend in emissions by sector from 1990 to 2004.

Figure 2-13: Emissions Allocated to Economic Sectors

Table 2-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg $CO_2$ Eq. and Percent of Total in 2004)

| Sector/Source | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Percent[a] |
|---|---|---|---|---|---|---|---|---|---|
| **Electricity Generation** | **1,846.4** | **2,202.4** | **2,213.3** | **2,315.9** | **2,284.4** | **2,280.1** | **2,308.5** | **2,337.8** | **33.0%** |
| $CO_2$ from Fossil Fuel Combustion | 1,795.5 | 2,154.9 | 2,165.6 | 2,269.3 | 2,237.3 | 2,233.5 | 2,262.2 | 2,290.6 | 32.4% |
| Stationary Combustion[d] | 8.1 | 9.6 | 9.6 | 10.0 | 9.8 | 9.8 | 10.0 | 10.1 | 0.1% |
| Electrical Transmission and Distribution[c] | 28.6 | 16.7 | 16.1 | 15.3 | 15.3 | 14.5 | 14.0 | 13.8 | 0.2% |
| Waste Combustion[b] | 11.4 | 17.5 | 18.0 | 18.3 | 19.1 | 19.4 | 19.9 | 19.9 | 0.3% |
| Limestone and Dolomite Use | 2.8 | 3.7 | 4.0 | 3.0 | 2.9 | 2.9 | 2.4 | 3.4 | + |
| **Transportation** | **1,520.3** | **1,753.4** | **1,819.3** | **1,866.9** | **1,852.7** | **1,898.0** | **1,898.9** | **1,955.1** | **27.6%** |
| $CO_2$ from Fossil Fuel Combustion | 1,461.4 | 1,660.3 | 1,722.4 | 1,766.9 | 1,753.6 | 1,798.8 | 1,801.0 | 1,855.5 | 26.2% |
| Mobile Combustion[d] | 47.1 | 57.4 | 56.4 | 55.4 | 52.0 | 49.4 | 46.5 | 44.4 | 0.6% |
| Substitution of ODS[e] | + | 23.5 | 28.2 | 32.6 | 36.1 | 38.9 | 41.2 | 45.0 | 0.6% |
| Non-Energy Use of Fuels | 11.9 | 12.1 | 12.3 | 12.1 | 11.1 | 10.9 | 10.1 | 10.2 | 0.1% |
| **Industry** | **1,438.9** | **1,452.4** | **1,411.0** | **1,409.7** | **1,366.6** | **1,346.7** | **1,342.7** | **1,377.3** | **19.5%** |
| $CO_2$ from Fossil Fuel Combustion | 804.8 | 814.5 | 789.2 | 812.3 | 811.0 | 789.8 | 800.3 | 813.1 | 11.5% |
| Non-Energy Use of Fuels | 99.6 | 131.6 | 138.8 | 117.7 | 114.7 | 116.4 | 113.7 | 132.8 | 1.9% |
| Stationary Combustion | 5.3 | 5.4 | 5.4 | 5.5 | 5.1 | 4.9 | 4.9 | 5.1 | 0.1% |
| Mobile Combustion | 0.6 | 0.7 | 0.7 | 0.8 | 0.9 | 0.9 | 0.9 | 1.0 | + |
| Coal Mining | 81.9 | 62.8 | 58.9 | 56.3 | 55.5 | 52.5 | 54.8 | 56.3 | 0.8% |
| Abandoned Coal Mines | 6.0 | 6.9 | 6.9 | 7.2 | 6.6 | 6.0 | 5.8 | 5.6 | 0.1% |
| Natural Gas Systems | 126.7 | 125.4 | 121.7 | 126.7 | 125.6 | 125.4 | 124.7 | 118.8 | 1.7% |
| Petroleum Systems | 34.4 | 29.7 | 28.5 | 27.8 | 27.4 | 26.8 | 25.9 | 25.7 | 0.4% |
| Natural Gas Flaring | 5.8 | 6.6 | 6.9 | 5.8 | 6.1 | 6.2 | 6.1 | 6.0 | 0.1% |
| Titanium Dioxide Production | 1.3 | 1.8 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.3 | + |
| Aluminum Production[h] | 25.5 | 15.4 | 15.4 | 15.2 | 8.5 | 9.9 | 8.4 | 7.2 | 0.1% |
| Iron and Steel Production[f] | 86.3 | 68.9 | 65.0 | 66.5 | 58.9 | 55.6 | 54.4 | 52.4 | 0.7% |
| Ferroalloy Production | 2.0 | 2.0 | 2.0 | 1.7 | 1.3 | 1.2 | 1.2 | 1.3 | + |
| Ammonia Manufacture | 19.3 | 21.9 | 20.6 | 19.6 | 16.7 | 18.5 | 15.3 | 16.9 | 0.2% |
| Cement Manufacture | 33.3 | 39.2 | 40.0 | 41.2 | 41.4 | 42.9 | 43.1 | 45.6 | 0.6% |
| Lime Manufacture | 11.2 | 13.9 | 13.5 | 13.3 | 12.8 | 12.3 | 13.0 | 13.7 | 0.2% |
| Limestone and Dolomite Use | 2.8 | 3.7 | 4.0 | 3.0 | 2.9 | 2.9 | 2.4 | 3.4 | + |
| Soda Ash Manufacture and Consumption | 4.1 | 4.3 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 | 0.1% |
| $CO_2$ Consumption | 0.9 | 0.9 | 0.8 | 1.0 | 0.8 | 1.0 | 1.3 | 1.2 | + |
| Silicon Carbide Consumption | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | + |
| Lead Production | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | + |
| Zinc Production | 0.9 | 1.1 | 1.1 | 1.1 | 1.0 | 0.9 | 0.5 | 0.5 | + |
| Petrochemical Production | 3.4 | 4.7 | 4.8 | 4.7 | 4.2 | 4.4 | 4.3 | 4.5 | 0.1% |
| Silicon Carbide Production | + | + | + | + | + | + | + | + | + |
| Phosphoric Acid Production | 1.5 | 1.6 | 1.5 | 1.4 | 1.3 | 1.3 | 1.4 | 1.4 | + |
| Adipic Acid | 15.2 | 6.0 | 5.5 | 6.0 | 4.9 | 5.9 | 6.2 | 5.7 | 0.1% |
| Nitric Acid | 17.8 | 20.9 | 20.1 | 19.6 | 15.9 | 17.2 | 16.7 | 16.6 | 0.2% |
| $N_2O$ Product Usage | 4.3 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 0.1% |
| HCFC-22 Production[g] | 35.0 | 40.1 | 30.4 | 29.8 | 19.8 | 19.8 | 12.3 | 15.6 | 0.2% |
| Semiconductor Manufacture[e] | 2.9 | 7.1 | 7.2 | 6.3 | 4.5 | 4.4 | 4.3 | 4.7 | 0.1% |
| Magnesium Production and Processing[c] | 5.4 | 5.8 | 6.0 | 3.2 | 2.6 | 2.6 | 3.0 | 2.7 | + |
| Substitution of ODS[e] | 0.1 | 3.9 | 4.4 | 4.7 | 5.1 | 5.7 | 6.5 | 7.9 | 0.1% |
| **Agriculture** | **486.3** | **541.6** | **523.9** | **509.5** | **514.4** | **511.0** | **484.2** | **491.3** | **6.9%** |
| $CO_2$ from Fossil Fuel | 46.3 | 57.4 | 59.8 | 50.2 | 50.2 | 52.3 | 44.3 | 50.3 | 0.7% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Combustion | | | | | | | | | |
| Stationary Combustion[d] | + | + | + | + | + | + | + | + | + |
| Mobile Combustion[d] | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | + |
| Enteric Fermentation | 117.9 | 116.7 | 116.8 | 115.6 | 114.6 | 114.7 | 115.1 | 112.6 | 1.6% |
| Manure Management[d] | 47.4 | 56.2 | 55.6 | 55.9 | 56.9 | 57.3 | 56.7 | 57.1 | 0.8% |
| Rice Cultivation | 7.1 | 7.9 | 8.3 | 7.5 | 7.6 | 6.8 | 6.9 | 7.6 | 0.1% |
| Agricultural Residue Burning[d] | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.2 | 1.4 | + |
| Agricultural Soil Management | 266.1 | 301.1 | 281.2 | 278.2 | 282.9 | 277.8 | 259.2 | 261.5 | 3.7% |
| Forest Soil Fertilization | 0.1 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | + |
| **Commercial** | **433.6** | **428.0** | **430.6** | **443.0** | **439.5** | **447.5** | **466.5** | **459.9** | **6.5%** |
| $CO_2$ from Fossil Fuel Combustion | 222.6 | 217.7 | 218.6 | 229.3 | 224.9 | 224.3 | 235.8 | 226.0 | 3.2% |
| Stationary Combustion[d] | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 | 1.1 | + |
| Substitution of ODS[e] | + | 17.4 | 20.3 | 23.8 | 27.1 | 30.9 | 34.8 | 39.0 | 0.6% |
| Landfills | 172.3 | 144.4 | 141.6 | 139.0 | 136.2 | 139.8 | 142.4 | 140.9 | 2.0% |
| Human Sewage | 12.9 | 14.9 | 15.4 | 15.5 | 15.6 | 15.6 | 15.8 | 16.0 | 0.2% |
| Wastewater Treatment | 24.8 | 32.6 | 33.6 | 34.3 | 34.7 | 35.8 | 36.6 | 36.9 | 0.5% |
| **Residential** | **349.4** | **353.3** | **372.6** | **390.4** | **381.6** | **380.1** | **399.8** | **391.1** | **5.5%** |
| $CO_2$ from Fossil Fuel Combustion | 338.0 | 333.5 | 352.3 | 369.9 | 361.5 | 360.0 | 378.8 | 369.6 | 5.2% |
| Stationary Combustion[d] | 5.5 | 4.0 | 4.2 | 4.4 | 3.9 | 3.5 | 3.9 | 3.7 | 0.1% |
| Substitution of ODS[e] | 0.3 | 9.6 | 9.8 | 10.1 | 10.3 | 10.6 | 11.0 | 11.3 | 0.2% |
| Settlement Soil Fertilization | 5.6 | 6.2 | 6.2 | 6.0 | 5.8 | 6.0 | 6.2 | 6.4 | 0.1% |
| **U.S. Territories** | **33.8** | **42.7** | **44.2** | **46.9** | **54.0** | **52.4** | **58.6** | **61.9** | **0.9%** |
| $CO_2$ from Fossil Fuel Combustion | 33.8 | 42.7 | 44.2 | 46.9 | 54.0 | 52.4 | 58.6 | 61.9 | 0.9% |
| **Total** | **6,109.0** | **6,773.7** | **6,814.9** | **6,982.3** | **6,893.1** | **6,915.8** | **6,959.1** | **7,074.4** | **100.0%** |
| **Sinks** | **(910.4)** | **(744.0)** | **(765.7)** | **(759.5)** | **(768.0)** | **(768.6)** | **(774.8)** | **(780.1)** | **-11.0%** |
| Forests | (773.4) | (618.8) | (637.9) | (631.0) | (634.0) | (634.6) | (635.8) | (637.2) | -9.0% |
| Urban Trees | (58.7) | (73.3) | (77.0) | (77.0) | (80.7) | (80.7) | (84.3) | (88.0) | -1.2% |
| Agricultural Soils | (53.8) | (41.0) | (41.1) | (42.6) | (44.3) | (44.1) | (45.3) | (45.6) | -0.6% |
| Landfilled Yard Trimmings | (24.5) | (10.9) | (9.8) | (8.9) | (9.0) | (9.3) | (9.4) | (9.3) | -0.1% |
| **Net Emissions (Sources and Sinks)** | **5,198.6** | **6,029.6** | **6,049.2** | **6,222.8** | **6,125.1** | **6,147.2** | **6,184.3** | **6,294.3** | **89.0%** |

Note: Includes all emissions of $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, and $SF_6$. Parentheses indicate negative values or sequestration. Totals may not sum due to independent rounding.
ODS (Ozone Depleting Substances)
+ Does not exceed 0.05 Tg $CO_2$ Eq. or 0.05%.
[a] Percent of total emissions for year 2004.
[b] Includes both $CO_2$ and $N_2O$.
[c] $SF_6$ emitted.
[d] Includes both $CH_4$ and $N_2O$.
[e] May include a mixture of HFCs, PFCs, and $SF_6$.
[f] Includes both $CH_4$ and $CO_2$.
[g] HFC-23 emitted.
[h] Includes both $CO_2$ and PFCs.

## Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 33 percent of total U.S. greenhouse gas emissions in 2004. Emissions increased by 27 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. The electricity generation sector in the United States is composed of traditional electric utilities as well as other entities, such as power marketers and nonutility power producers. The majority of electricity generated by these entities was through the combustion of coal in boilers to produce high-pressure steam that is passed through a turbine. Table 2-15 provides a detailed summary of emissions from electricity generation-related activities.

Table 2-15: Electricity Generation-Related Greenhouse Gas Emissions (Tg $CO_2$ Eq.)

| Gas/Fuel Type or Source | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **1,809.2** | **2,175.7** | **2,187.2** | **2,290.2** | **2,258.8** | **2,255.3** | **2,283.9** | **2,313.3** |
| $CO_2$ from Fossil Fuel Combustion | 1,795.5 | 2,154.9 | 2,165.6 | 2,269.3 | 2,237.3 | 2,233.5 | 2,262.2 | 2,290.6 |
| *Coal* | *1,517.3* | *1,801.2* | *1,807.7* | *1,896.6* | *1,845.9* | *1,849.6* | *1,887.2* | *1,897.1* |
| *Natural Gas* | *176.9* | *249.1* | *260.9* | *281.4* | *289.5* | *305.6* | *277.6* | *295.8* |
| *Petroleum* | *100.9* | *104.2* | *96.6* | *91.0* | *101.6* | *77.8* | *97.0* | *97.3* |
| *Geothermal* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* | *0.4* |
| Waste Combustion | 10.9 | 17.1 | 17.6 | 17.9 | 18.6 | 18.9 | 19.4 | 19.4 |
| Limestone and Dolomite Use | 2.8 | 3.7 | 4.0 | 3.0 | 2.9 | 2.9 | 2.4 | 3.4 |
| **$CH_4$** | **0.6** | **0.7** | **0.7** | **0.7** | **0.7** | **0.7** | **0.7** | **0.7** |
| Stationary Combustion* | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| **$N_2O$** | **8.0** | **9.3** | **9.3** | **9.7** | **9.6** | **9.6** | **9.8** | **9.9** |
| Stationary Combustion* | 7.6 | 8.9 | 8.9 | 9.3 | 9.1 | 9.1 | 9.3 | 9.4 |
| Waste Combustion | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 |
| **$SF_6$** | **28.6** | **16.7** | **16.1** | **15.3** | **15.3** | **14.5** | **14.0** | **13.8** |
| Electrical Transmission and Distribution | 28.6 | 16.7 | 16.1 | 15.3 | 15.3 | 14.5 | 14.0 | 13.8 |
| **Total** | **1,846.4** | **2,202.4** | **2,213.3** | **2,315.9** | **2,284.4** | **2,280.1** | **2,308.5** | **2,337.8** |

Note: Totals may not sum due to independent rounding.
* Includes only stationary combustion emissions related to the generation of electricity.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity (EIA 2005a and Duffield 2005). These three source categories include $CO_2$ from fossil fuel combustion, $CH_4$ and $N_2O$ from stationary sources, and $SF_6$ from electrical transmission and distribution systems.[5]

When emissions from electricity are distributed among these sectors, industry accounts for the largest share of U.S. greenhouse gas emissions (30 percent). Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption. Transportation activities remain the second largest contributor to total U.S. emissions (28 percent). In all sectors except agriculture, $CO_2$ accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-16 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-14 shows the trend in these emissions by sector from 1990 to 2004.

Figure 2-14: Emissions with Electricity Distributed to Economic Sectors

[5] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

Table 2-16: U.S Greenhouse Gas Emissions by "Economic Sector" and Gas with Electricity-Related Emissions Distributed (Tg $CO_2$ Eq.) and Percent of Total in 2004

| Sector/Gas | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Percent[a] |
|---|---|---|---|---|---|---|---|---|---|
| **Industry** | **2,074.6** | **2,210.3** | **2,174.4** | **2,186.1** | **2,073.6** | **2,042.0** | **2,066.0** | **2,103.0** | **29.7%** |
| Direct Emissions | 1,438.9 | 1,452.4 | 1,411.0 | 1,409.7 | 1,366.6 | 1,346.7 | 1,342.7 | 1,377.3 | 19.5% |
| $CO_2$ | 1,082.3 | 1,120.8 | 1,098.4 | 1,099.2 | 1,081.4 | 1,062.0 | 1,065.4 | 1,101.3 | 15.6% |
| $CH_4$ | 253.8 | 230.0 | 221.3 | 223.2 | 219.7 | 215.3 | 216.0 | 211.3 | 3.0% |
| $N_2O$ | 41.1 | 35.5 | 34.2 | 34.3 | 29.4 | 31.6 | 31.4 | 31.0 | 0.4% |
| HFCs, PFCs, and $SF_6$ | 61.8 | 66.1 | 57.1 | 53.0 | 36.0 | 37.7 | 30.0 | 33.7 | 0.5% |
| Electricity-Related | 635.7 | 757.9 | 763.4 | 776.5 | 707.0 | 695.4 | 723.3 | 725.7 | 10.3% |
| $CO_2$ | 622.9 | 748.7 | 754.4 | 767.9 | 699.1 | 687.8 | 715.6 | 718.1 | 10.2% |
| $CH_4$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | + |
| $N_2O$ | 2.8 | 3.2 | 3.2 | 3.3 | 3.0 | 2.9 | 3.1 | 3.1 | + |
| $SF_6$ | 9.9 | 5.8 | 5.5 | 5.1 | 4.7 | 4.4 | 4.4 | 4.3 | 0.1% |
| **Transportation** | **1,523.4** | **1,756.5** | **1,822.5** | **1,870.3** | **1,856.2** | **1,901.4** | **1,903.2** | **1,959.8** | **27.7%** |
| Direct Emissions | 1,520.3 | 1,753.4 | 1,819.3 | 1,866.9 | 1,852.7 | 1,898.0 | 1,898.9 | 1,955.1 | 27.6% |
| $CO_2$ | 1,473.2 | 1,672.5 | 1,734.6 | 1,778.9 | 1,764.6 | 1,809.7 | 1,811.1 | 1,865.7 | 26.4% |
| $CH_4$ | 4.5 | 3.6 | 3.4 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 0.0% |
| $N_2O$ | 42.6 | 53.8 | 53.0 | 52.1 | 48.9 | 46.4 | 43.7 | 41.7 | 0.6% |
| HFCs[b] | + | 23.5 | 28.2 | 32.57 | 36.10 | 38.95 | 41.22 | 45.03 | 0.6% |
| Electricity-Related | 3.1 | 3.1 | 3.2 | 3.38 | 3.44 | 3.38 | 4.30 | 4.69 | 0.1% |
| $CO_2$ | 3.0 | 3.1 | 3.1 | 3.3 | 3.4 | 3.3 | 4.3 | 4.6 | 0.1% |
| $CH_4$ | + | + | + | + | + | + | + | + | + |
| $N_2O$ | + | + | + | + | + | + | + | + | + |
| $SF_6$ | + | + | + | + | + | + | + | + | + |
| **Commercial** | **979.2** | **1,102.0** | **1,115.8** | **1,171.8** | **1,190.8** | **1,191.4** | **1,204.3** | **1,211.0** | **17.1%** |
| Direct Emissions | 433.6 | 428.0 | 430.6 | 443.0 | 439.5 | 447.5 | 466.5 | 459.9 | 6.5% |
| $CO_2$ | 222.6 | 217.7 | 218.6 | 229.3 | 224.9 | 224.3 | 235.8 | 226.0 | 3.2% |
| $CH_4$ | 197.8 | 177.7 | 176.0 | 174.1 | 171.6 | 176.4 | 179.7 | 178.5 | 2.5% |
| $N_2O$ | 13.3 | 15.2 | 15.7 | 15.8 | 15.9 | 15.9 | 16.1 | 16.3 | 0.2% |
| HFCs | + | 17.4 | 20.3 | 23.8 | 27.1 | 30.9 | 34.8 | 39.0 | 0.6% |
| Electricity-Related | 545.6 | 674.0 | 685.1 | 728.8 | 751.3 | 743.9 | 737.8 | 751.1 | 10.6% |
| $CO_2$ | 534.6 | 665.9 | 677.1 | 720.7 | 742.9 | 735.8 | 729.9 | 743.3 | 10.5% |
| $CH_4$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | + |
| $N_2O$ | 2.4 | 2.8 | 2.9 | 3.1 | 3.2 | 3.1 | 3.1 | 3.2 | + |
| $SF_6$ | 8.5 | 5.1 | 5.0 | 4.8 | 5.0 | 4.7 | 4.5 | 4.4 | 0.1% |
| **Residential** | **950.8** | **1,060.0** | **1,083.2** | **1,140.0** | **1,136.2** | **1,154.1** | **1,182.9** | **1,181.9** | **16.7%** |
| Direct Emissions | 349.4 | 353.3 | 372.6 | 390.4 | 381.6 | 380.1 | 399.8 | 391.1 | 5.5% |
| $CO_2$ | 338.0 | 333.5 | 352.3 | 369.9 | 361.5 | 360.0 | 378.8 | 369.6 | 5.2% |
| $CH_4$ | 4.4 | 3.1 | 3.3 | 3.5 | 3.1 | 2.7 | 3.0 | 2.9 | + |
| $N_2O$ | 6.7 | 7.0 | 7.1 | 7.0 | 6.7 | 6.8 | 7.0 | 7.3 | 0.1% |
| HFCs | 0.3 | 9.6 | 9.8 | 10.1 | 10.3 | 10.6 | 11.0 | 11.3 | 0.2% |
| Electricity-Related | 601.4 | 706.7 | 710.7 | 749.6 | 754.6 | 773.9 | 783.1 | 790.8 | 11.2% |
| $CO_2$ | 589.2 | 698.1 | 702.3 | 741.3 | 746.1 | 765.5 | 774.8 | 782.6 | 11.1% |
| $CH_4$ | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | + |
| $N_2O$ | 2.6 | 3.0 | 3.0 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | + |
| $SF_6$ | 9.3 | 5.4 | 5.2 | 4.9 | 5.1 | 4.9 | 4.8 | 4.7 | 0.1% |
| **Agriculture** | **547.1** | **602.4** | **575.0** | **567.2** | **582.6** | **574.5** | **544.3** | **556.9** | **7.9%** |
| Direct Emissions | 486.3 | 541.6 | 523.9 | 509.5 | 514.4 | 511.0 | 484.2 | 491.3 | 6.9% |
| $CO_2$ | 46.3 | 57.4 | 59.8 | 50.2 | 50.2 | 52.3 | 44.3 | 50.3 | 0.7% |
| $CH_4$ | 157.0 | 164.4 | 164.2 | 162.1 | 162.1 | 161.7 | 162.1 | 160.6 | 2.3% |
| $N_2O$ | 283.1 | 319.7 | 299.9 | 297.2 | 302.2 | 297.0 | 277.8 | 280.4 | 4.0% |
| Electricity-Related | 60.7 | 60.7 | 50.9 | 57.6 | 68.0 | 63.4 | 60.0 | 65.4 | **0.9%** |
| $CO_2$ | 59.5 | 59.9 | 50.3 | 56.9 | 67.3 | 62.8 | 59.3 | 64.7 | 0.9% |
| $CH_4$ | + | + | + | + | + | + | + | + | + |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | + |
| $SF_6$ | 0.9 | 0.5 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | + |
| **U.S. Territories** | **33.8** | **42.7** | **44.2** | **46.9** | **54.0** | **52.4** | **58.6** | **61.9** | **0.9%** |
| $CO_2$ | 33.8 | 42.7 | 44.2 | 46.9 | 54.0 | 52.4 | 58.6 | 61.9 | 0.9% |
| **Total** | **6,109.0** | **6,773.7** | **6,814.9** | **6,982.3** | **6,893.1** | **6,915.8** | **6,959.1** | **7,074.4** | **100.0%** |

Note: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector. Totals may not sum due to independent rounding.
+ Does not exceed 0.05 Tg $CO_2$ Eq. or 0.05%.
[a] Percents for year 2004.
[b] Includes primarily HFC-134a.

## Transportation

Transportation activities accounted for 28 percent of U.S. greenhouse gas emissions in 2004. Table 2-17 provides a detailed summary of greenhouse gas emissions from transportation-related activities. Total emissions in Table 2-17 differ slightly from those shown in Table 2-16 primarily because the table below excludes a few minor non-transportation mobile sources, such as construction and industrial equipment.

From 1990 to 2004, transportation emissions rose by 29 percent due, in part, to increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet. Since the 1970s, the number of highway vehicles registered in the United States has increased faster than the overall population, according to the Federal Highway Administration (FHWA). Likewise, the number of miles driven (up 38 percent from 1990 to 2004) and the gallons of gasoline consumed each year in the United States have increased steadily since the 1980s, according to the FHWA and Energy Information Administration, respectively. These increases in motor vehicle usage are the result of a confluence of factors including population growth, economic growth, urban sprawl, low fuel prices, and increasing popularity of sport utility vehicles and other light-duty trucks that tend to have lower fuel efficiency. A similar set of social and economic trends has led to a significant increase in air travel and freight transportation by both air and road modes during the time series.

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with nearly two-thirds being related to gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder. The primary driver of transportation-related emissions was $CO_2$ from fossil fuel combustion, which increased by 27 percent from 1990 to 2004. This rise in $CO_2$ emissions, combined with an increase of 45.0 Tg $CO_2$ Eq. in HFC emissions over the same period, led to an increase in overall emissions from transportation activities of 29 percent.

Table 2-17: Transportation-Related Greenhouse Gas Emissions (Tg $CO_2$ Eq.)

| Gas/Vehicle Type | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | **1,476.2** | **1,675.6** | **1,737.8** | **1,782.3** | **1,768.1** | **1,813.1** | **1,815.5** | **1,870.4** |
| Passenger Cars | 618.9 | 621.5 | 631.2 | 633.4 | 636.5 | 651.6 | 631.3 | 636.4 |
| Light-Duty Trucks | 315.8 | 437.3 | 455.0 | 458.3 | 462.2 | 474.8 | 509.6 | 526.0 |
| Other Trucks | 225.3 | 306.5 | 322.4 | 337.9 | 337.0 | 351.0 | 347.3 | 365.3 |
| Buses | 8.2 | 9.8 | 11.0 | 10.8 | 9.9 | 9.5 | 10.3 | 10.3 |
| Aircraft[a] | 177.2 | 181.3 | 186.8 | 193.2 | 183.5 | 174.9 | 171.8 | 179.6 |
| Ships and Boats | 43.6 | 27.3 | 37.5 | 55.1 | 48.1 | 57.0 | 49.7 | 54.4 |
| Locomotives | 37.8 | 43.0 | 44.6 | 44.6 | 44.8 | 45.2 | 47.1 | 49.8 |
| Other[b] | 49.5 | 48.8 | 49.4 | 48.9 | 46.2 | 49.0 | 48.4 | 48.7 |
| *International Bunker Fuels*[c] | *93.6* | *103.3* | *102.6* | *102.2* | *98.5* | *89.5* | *84.1* | *94.5* |
| **$CH_4$** | **4.5** | **3.6** | **3.4** | **3.3** | **3.1** | **2.9** | **2.8** | **2.7** |
| Passenger Cars | 2.6 | 1.8 | 1.7 | 1.6 | 1.5 | 1.4 | 1.3 | 1.3 |
| Light-Duty Trucks | 1.4 | 1.3 | 1.2 | 1.1 | 1.1 | 1.0 | 0.9 | 0.9 |
| Other Trucks and Buses | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Aircraft | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ships and Boats | 0.1 | + | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Locomotives | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Motorcycles | + | + | + | + | + | + | + | + |
| *International Bunker Fuels*[c] | *0.2* | *0.2* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* |
| **$N_2O$** | **42.7** | **53.9** | **53.1** | **52.1** | **48.9** | **46.4** | **43.7** | **41.6** |
| Passenger Cars | 25.4 | 26.7 | 25.9 | 25.1 | 23.9 | 22.9 | 21.8 | 21.0 |
| Light-Duty Trucks | 14.1 | 23.7 | 23.5 | 23.1 | 21.2 | 19.7 | 18.1 | 16.7 |
| Other Trucks and Buses | 0.8 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 |
| Aircraft | 1.7 | 1.8 | 1.8 | 1.9 | 1.8 | 1.7 | 1.7 | 1.8 |
| Ships and Boats | 0.4 | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 |
| Locomotives | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| Motorcycles | + | + | + | + | + | + | + | + |
| *International Bunker Fuels*[c] | *1.0* | *1.0* | *0.9* | *0.9* | *0.9* | *0.8* | *0.8* | *0.9* |
| **HFCs** | + | 23.5 | 28.2 | 32.6 | 36.1 | 38.9 | 41.2 | 45.0 |
| Mobile Air Conditioners[d] | + | 16.5 | 19.7 | 22.8 | 25.3 | 27.4 | 28.9 | 31.9 |
| Refrigerated Transport | + | 7.0 | 8.5 | 9.8 | 10.8 | 11.5 | 12.3 | 13.1 |
| **Total** | **1,523.4** | **1,756.6** | **1,822.6** | **1,870.3** | **1,856.2** | **1,901.4** | **1,903.1** | **1,959.8** |

+ Does not exceed 0.05 Tg $CO_2$ Eq.
Note: Totals may not sum due to independent rounding.
[a] Aircraft emissions consist of emissions from all jet fuel (less bunker fuels) and aviation gas consumption.
[b] "Other" $CO_2$ emissions include motorcycles, pipelines, and lubricants.
[c] Emissions from International Bunker Fuels include emissions from both civilian and military activities, but are not included in totals.
[d] Includes primarily HFC-134a.

[BEGIN BOX]

Box 2-2: Methodology for Aggregating Emissions by Economic Sector

In order to aggregate emissions by economic sector, source category emission estimates were generated according to the methodologies outlined in the appropriate sections of this report. Those emissions were then simply reallocated into economic sectors. In most cases, the IPCC subcategories distinctly fit into an apparent economic sector category. Several exceptions exist, and the methodologies used to disaggregate these subcategories are described below:

- *Agricultural $CO_2$ Emissions from Fossil Fuel Combustion, and non-$CO_2$ emissions from Stationary and Mobile Combustion.* Emissions from on-farm energy use were accounted for in the Energy chapter as part of the industrial and transportation end-use sectors. To calculate agricultural emissions related to fossil fuel combustion, energy consumption estimates were obtained from economic survey data from the U.S. Department of Agriculture (Duffield 2005) and fuel sales data (EIA 1991 through 2005). To avoid double-counting, emission estimates of $CO_2$ from fossil fuel combustion and non-$CO_2$ from stationary and mobile sources were subtracted from the industrial economic sector, although some of these fuels may have been originally accounted for under the transportation end-use sector.

- *Landfills, Wastewater Treatment, and Human Sewage.* $CH_4$ emissions from landfills and wastewater treatment, as well as $N_2O$ emissions from human sewage, were allocated to the commercial sector.

- *Waste Combustion.* $CO_2$ and $N_2O$ emissions from waste combustion were allocated completely to the electricity generation sector since nearly all waste combustion occurs in waste-to-energy facilities.

- *Limestone and Dolomite Use.* $CO_2$ emissions from limestone and dolomite use are allocated to the electricity generation (50 percent) and industrial (50 percent) sectors, because 50 percent of the total emissions for this source are used in flue gas desulfurization.

- *Substitution of Ozone Depleting Substances.* All greenhouse gas emissions resulting from the substitution of ozone depleting substances were placed in the industrial economic sector, with the exception of emissions from domestic, commercial, mobile and transport refrigeration/air-conditioning systems, which were placed in the residential, commercial, and transportation sectors, respectively. Emissions from non-MDI aerosols were attributed to the residential economic sector.

- *Settlement Soil Fertilization*, *Forest Soil Fertilization.* Emissions from settlement soil fertilization were allocated to the residential economic sector; forest soil fertilization was allocated to the agriculture economic sector.

[END BOX]

## 2.3. Indirect Greenhouse Gas Emissions (CO, $NO_x$, NMVOCs, and $SO_2$)

The reporting requirements of the UNFCCC[6] request that information be provided on indirect greenhouse gases, which include CO, $NO_x$, NMVOCs, and $SO_2$. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of $SO_2$, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases. Carbon monoxide is produced when carbon-containing fuels are combusted incompletely. Nitrogen oxides (i.e., NO and $NO_2$) are created by lightning, fires, fossil fuel combustion, and in the stratosphere from nitrous oxide ($N_2O$). Non-$CH_4$ volatile organic compounds—which include hundreds of organic compounds that participate in atmospheric chemical reactions (i.e., propane, butane, xylene, toluene, ethane and many others)—are emitted primarily from transportation, industrial processes, and non-industrial consumption of organic solvents. In the United States, $SO_2$ is primarily emitted from coal combustion for electric power generation and the metals industry. Sulfur-containing compounds emitted into the atmosphere tend to exert a negative radiative forcing (i.e., cooling) and therefore are discussed separately.

One important indirect climate change effect of NMVOCs and $NO_x$ is their role as precursors for tropospheric ozone formation. They can also alter the atmospheric lifetimes of other greenhouse gases. Another example of indirect greenhouse gas formation into greenhouse gases is carbon monoxide's interaction with the hydroxyl radical—the major atmospheric sink for $CH_4$ emissions—to form $CO_2$. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy $CH_4$.

Since 1970, the United States has published estimates of annual emissions of CO, $NO_x$, NMVOCs, and $SO_2$ (EPA 2005),[7] which are regulated under the Clean Air Act. Table 2-18 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, $NO_x$, and NMVOCs.

Table 2-18: Emissions of $NO_x$, CO, NMVOCs, and $SO_2$ (Gg)

| Gas/Activity | 1990 | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **$NO_x$** | **22,860** | | **21,964** | **20,530** | **20,288** | **19,414** | **18,850** | **17,995** | **17,076** |
| Stationary Fossil Fuel Combustion | 9,884 | | 9,419 | 8,344 | 8,002 | 7,667 | 7,522 | 7,138 | 6,662 |
| Mobile Fossil Fuel Combustion | 12,134 | | 11,592 | 11,300 | 11,395 | 10,823 | 10,389 | 9,916 | 9,465 |
| Oil and Gas Activities | 139 | | 130 | 109 | 111 | 113 | 135 | 135 | 135 |

6 See <http://unfccc.int/resource/docs/cop8/08.pdf>.

7 $NO_x$ and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2004).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Waste Combustion | 82 | 145 | 143 | 114 | 114 | 134 | 134 | 134 |
| Industrial Processes | 591 | 637 | 595 | 626 | 656 | 630 | 631 | 632 |
| Solvent Use | 1 | 3 | 3 | 3 | 3 | 6 | 6 | 6 |
| Agricultural Burning | 28 | 35 | 34 | 35 | 35 | 33 | 34 | 39 |
| Waste | + | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO** | **130,580** | **98,984** | **94,361** | **92,895** | **89,329** | **87,428** | **87,518** | **87,599** |
| Stationary Fossil Fuel Combustion | 4,999 | 3,927 | 5,024 | 4,340 | 4,377 | 4,020 | 4,020 | 4,020 |
| Mobile Fossil Fuel Combustion | 119,482 | 87,940 | 83,484 | 83,680 | 79,972 | 78,574 | 78,574 | 78,574 |
| Oil and Gas Activities | 302 | 332 | 145 | 146 | 147 | 116 | 116 | 116 |
| Waste Combustion | 978 | 2,826 | 2,725 | 1,670 | 1,672 | 1,672 | 1,672 | 1,672 |
| Industrial Processes | 4,124 | 3,163 | 2,156 | 2,217 | 2,339 | 2,286 | 2,286 | 2,286 |
| Solvent Use | 4 | 1 | 46 | 46 | 45 | 46 | 46 | 46 |
| Agricultural Burning | 689 | 789 | 767 | 790 | 770 | 706 | 796 | 877 |
| Waste | 1 | 5 | 13 | 8 | 8 | 8 | 8 | 8 |
| **NMVOCs** | **20,937** | **16,403** | **15,869** | **15,228** | **15,048** | **14,217** | **13,877** | **13,556** |
| Stationary Fossil Fuel Combustion | 912 | 1,016 | 1,045 | 1,077 | 1,080 | 923 | 922 | 922 |
| Mobile Fossil Fuel Combustion | 10,933 | 7,742 | 7,586 | 7,230 | 6,872 | 6,560 | 6,212 | 5,882 |
| Oil and Gas Activities | 555 | 440 | 414 | 389 | 400 | 340 | 341 | 341 |
| Waste Combustion | 222 | 326 | 302 | 257 | 258 | 281 | 282 | 282 |
| Industrial Processes | 2,426 | 2,047 | 1,813 | 1,773 | 1,769 | 1,723 | 1,725 | 1,727 |
| Solvent Use | 5,217 | 4,671 | 4,569 | 4,384 | 4,547 | 4,256 | 4,262 | 4,267 |
| Agricultural Burning | NA | NA | NA | NA | NA | NA | NA | NA |
| Waste | 673 | 161 | 140 | 119 | 122 | 133 | 134 | 134 |
| **$SO_2$** | **20,936** | **17,189** | **15,917** | **14,829** | **14,452** | **13,928** | **14,208** | **13,910** |
| Stationary Fossil Fuel Combustion | 18,407 | 15,191 | 13,915 | 12,848 | 12,461 | 11,946 | 12,220 | 11,916 |
| Mobile Fossil Fuel Combustion | 793 | 665 | 704 | 632 | 624 | 631 | 637 | 644 |
| Oil and Gas Activities | 390 | 310 | 283 | 286 | 289 | 315 | 315 | 315 |
| Waste Combustion | 39 | 30 | 30 | 29 | 30 | 24 | 24 | 24 |
| Industrial Processes | 1,306 | 991 | 984 | 1,031 | 1,047 | 1,009 | 1,009 | 1,009 |
| Solvent Use | + | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Agricultural Burning | NA | NA | NA | NA | NA | NA | NA | NA |
| Waste | + | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Source: (EPA 2005) except for estimates from field burning of agricultural residues.
+ Does not exceed 0.5 Gg
NA (Not Available)
Note: Totals may not sum due to independent rounding.

[BEGIN BOX]

Box 2-3: Sources and Effects of Sulfur Dioxide

Sulfur dioxide ($SO_2$) emitted into the atmosphere through natural and anthropogenic processes affects the Earth's radiative budget through its photochemical transformation into sulfate aerosols that can (1) scatter radiation from the sun back to space, thereby reducing the radiation reaching the Earth's surface; (2) affect cloud formation; and (3) affect atmospheric chemical composition (e.g., by providing surfaces for heterogeneous chemical reactions). The indirect effect of sulfur-derived aerosols on radiative forcing can be considered in two parts. The first indirect effect is the aerosols' tendency to decrease water droplet size and increase water droplet concentration in the atmosphere. The second indirect effect is the tendency of the reduction in cloud droplet size to affect precipitation by increasing cloud lifetime and thickness. Although still highly uncertain, the radiative forcing estimates from both the first and the second indirect effect are believed to be negative, as is the combined radiative forcing of the two (IPCC 2001). However, because $SO_2$ is short-lived and unevenly distributed in the atmosphere, its radiative forcing impacts are highly uncertain.

Sulfur dioxide is also a major contributor to the formation of regional haze, which can cause significant increases in acute and chronic respiratory diseases. Once $SO_2$ is emitted, it is chemically transformed in the atmosphere and returns to the Earth as the primary source of acid rain. Because of these harmful effects, the United States has regulated $SO_2$ emissions in the Clean Air Act.

Electricity generation is the largest anthropogenic source of $SO_2$ emissions in the United States, accounting for 86 percent in 2004. Coal combustion contributes nearly all of those emissions (approximately 92 percent). Sulfur dioxide emissions have decreased in recent years, primarily as a result of electric power generators switching from high sulfur to low sulfur coal and installing flue gas desulfurization equipment.

[END BOX]

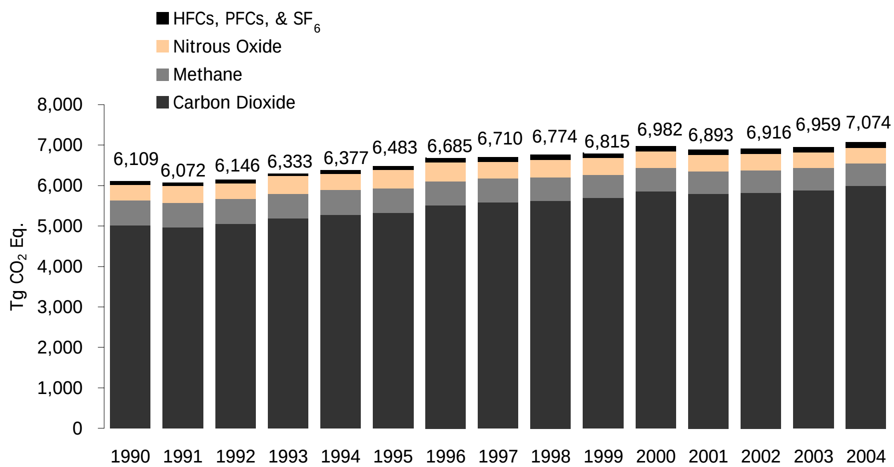



Figure 2-1: U.S. Greenhouse Gas Emissions by Gas

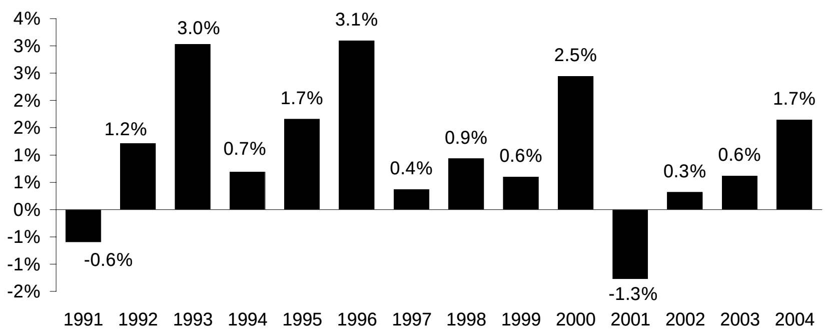



Figure 2-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

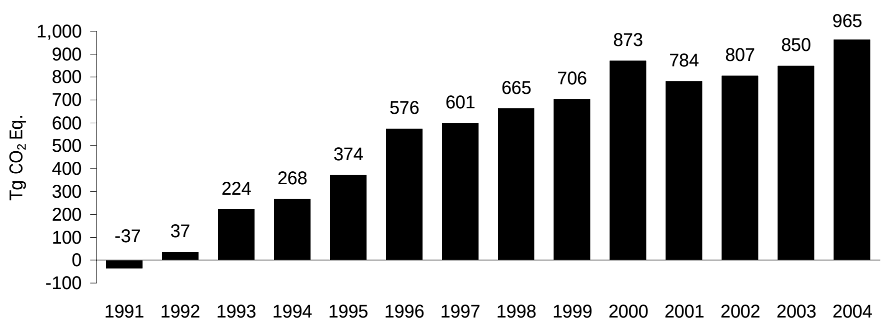



Figure 2-3: Cumulative Change in U.S. Greenhouse Gas Emissions Relative to 1990

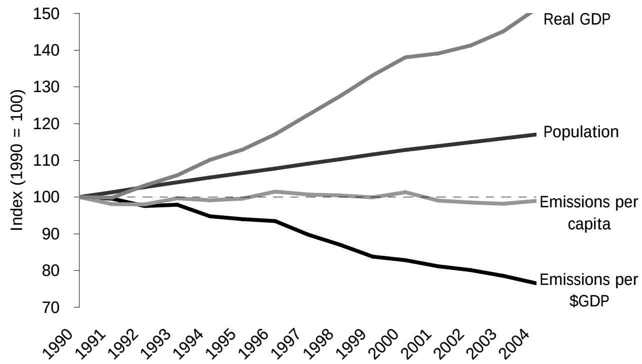
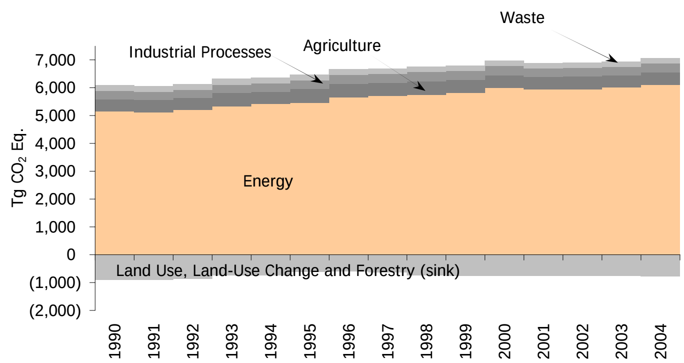



Figure 2-4: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product




Note: Relatively smaller amounts of GWP-weighted emissions are also emitted from the Land-Use Change and Forestry sector and the Solvent and Other Product
Figure 2-5: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

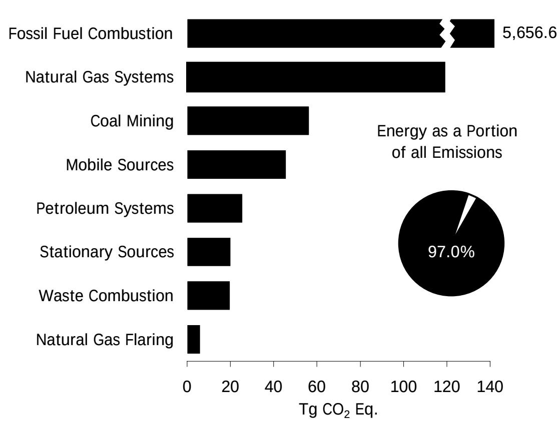
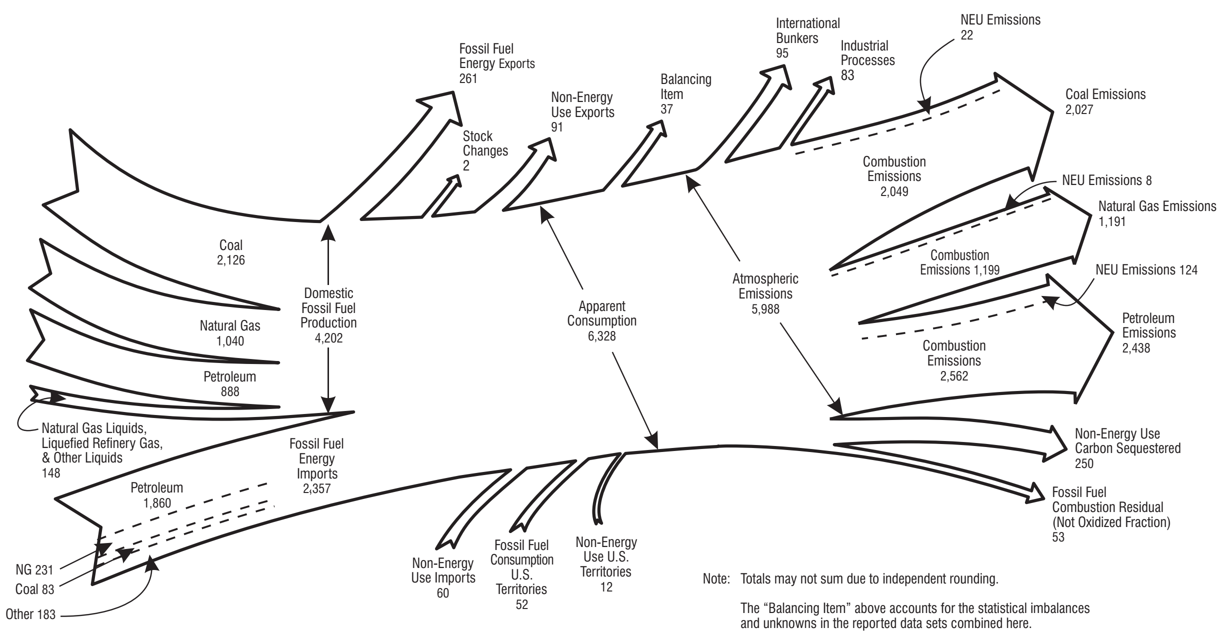



Figure 2-6: 2004 Energy Sector Greenhouse Gas Sources

**Figure 2-7**

## 2004 U.S. Fossil Carbon Flows (Tg $CO_2$ Eq.)




Note: Totals may not sum due to independent rounding.

The "Balancing Item" above accounts for the statistical imbalances and unknowns in the reported data sets combined here.

NEU = Non-Energy Use
NG = Natural Gas

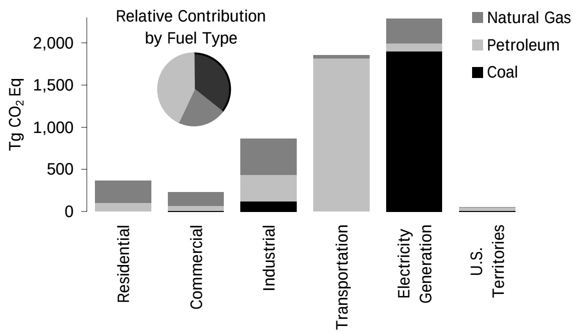



Figure 2-8: 2004 $CO_2$ Emissions from Fossil Fuel Combustion by Sector and Fuel Type
Note: Electricity generation also includes emissions of less than 1 Tg $CO_2$ Eq. from geothermal-based electricit

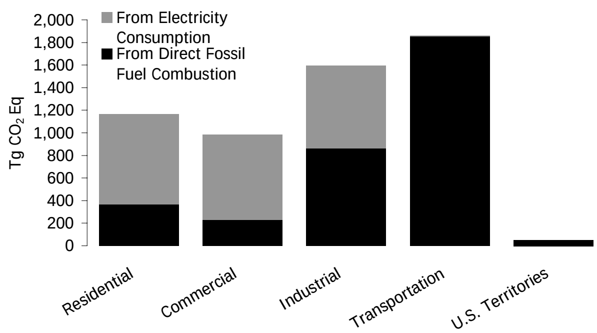



Figure 2-9: 2004 End-Use Sector Emissions of $CO_2$ from Fossil Fuel Combustion

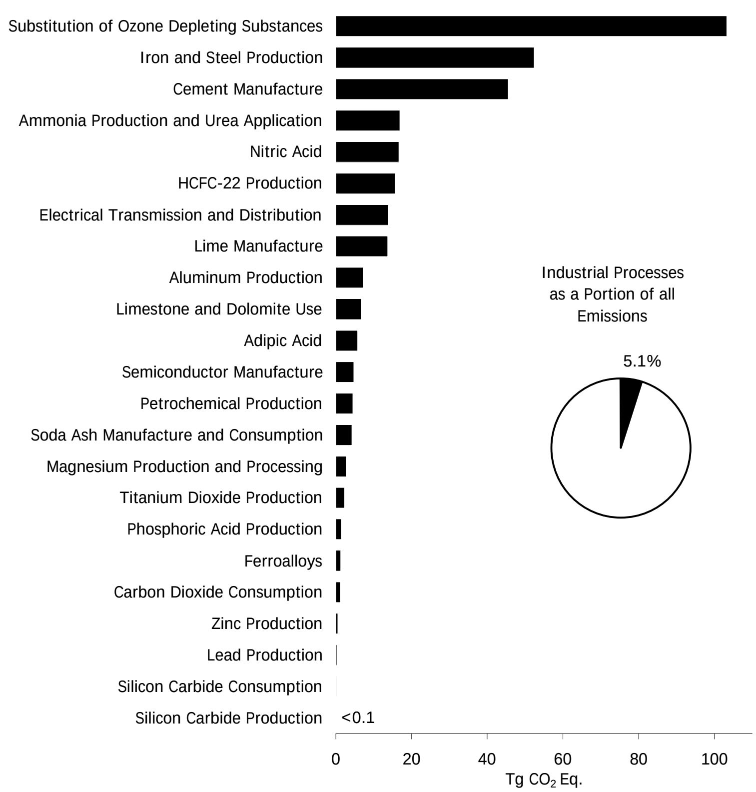



Figure 2-10: 2004 Industrial Processes Chapter Greenhouse Gas Sources

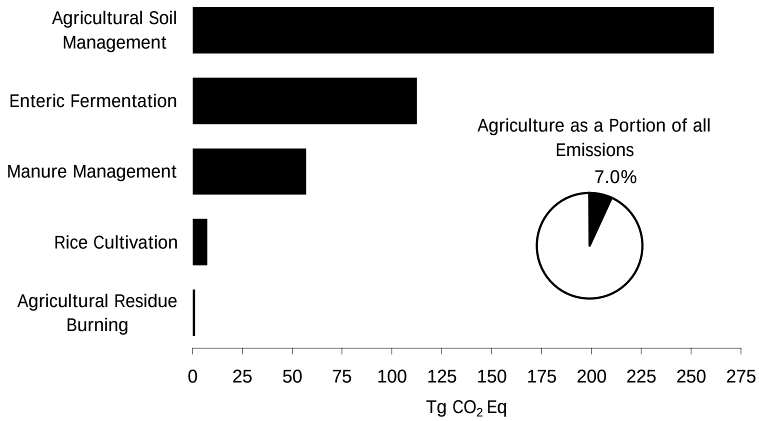



Figure 2-11:  2004 Agriculture Chapter GHG Sources

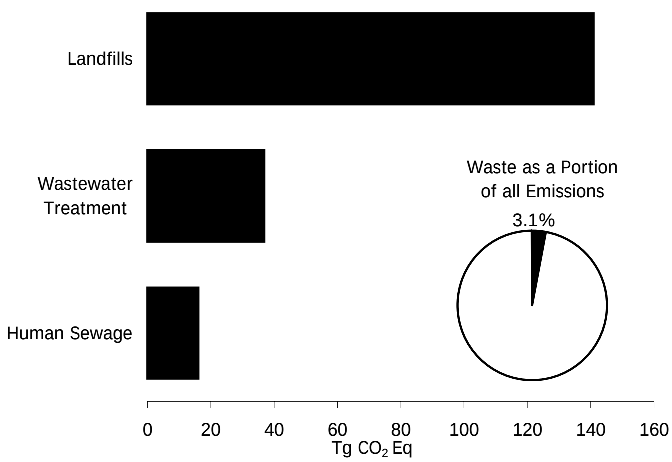



Figure 2-12:  2004 Waste Chapter Greenhouse Gas Sources

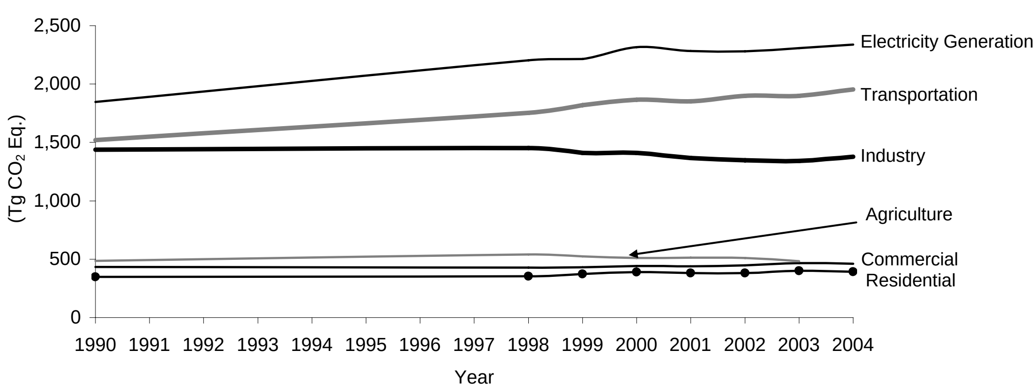



Figure 2-13: Emissions Allocated to Economic Sectors

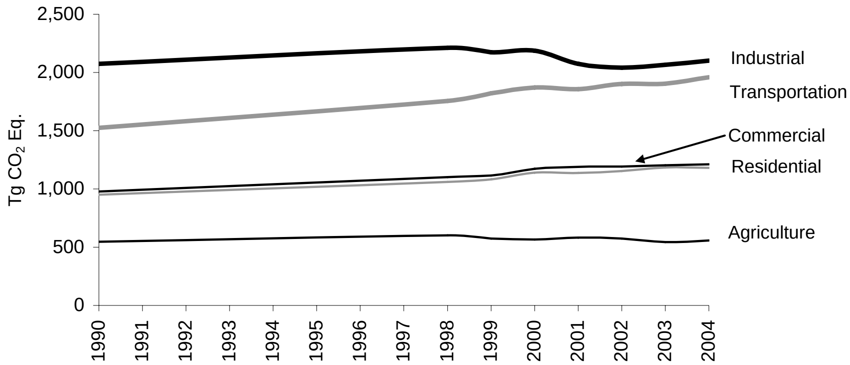



Figure 2-14:  Emissions with Electricity Distributed to Economic Sectors

**Descriptions of Figures: Trends in Greenhouse Gas Emissions**

Figure 2-1 illustrates U.S. greenhouse gas emissions by gas, with a cumulative total of $CO_2$ equivalent. There is generally an upward trend, starting from 6,109 Tg $CO_2$ eq. in 1990 and ending with 7,074 Tg $CO_2$ eq. in 2004. The only exception to this trend is 1991, where emissions were 6,072 Tg $CO_2$ eq, down from 6,109 Tg $CO_2$ eq in 1990. They increased again in 1992 to 6,146 Tg $CO_2$ eq.

Figure 2-2 depicts the annual percent change in U.S. greenhouse gas emissions since 1990. The change in 1991 was -0.6%. In 1992, it was 1.2%. In 1993, it was 3.0%. In 1994, it was 0.7%. In 1995, it was 1.7%. In 1996, it was 3.1%. In 1997, it was 0.4%. In 1998, it was 0.9%. In 1999, it was 0.6%. In 2000, it was 2.5%. In 2001, it was -1.3%. In 2002, it was 0.3%, in 2003, it was 0.6%, and in 2004, it was 1.7%.

Figure 2-3 depicts the absolute change in U.S. greenhouse gas emissions since 1990. The change in 1991 was -37 Tg $CO_2$ Eq. In 1992, it was 37 Tg $CO_2$ Eq. In 1993, it was 224 Tg $CO_2$ Eq. In 1994, it was 268 Tg $CO_2$ Eq . In 1995, it was 374 Tg $CO_2$ Eq . In 1996, it was 576 Tg $CO_2$ Eq. In 1997, it was 601 Tg $CO_2$ Eq. In 1998, it was 665 Tg $CO_2$ Eq. In 1999, it was 706 Tg $CO_2$ Eq. In 2000, it was 873 Tg $CO_2$ Eq. In 2001, it was 784 Tg $CO_2$ Eq. In 2002, it was 807 Tg $CO_2$ Eq. In 2003, it was 850 Tg $CO_2$ Eq. and in 2004, it was 965 Tg $CO_2$ Eq.

Figure 2-4 illustrates U.S. greenhouse gas emissions per capita and per dollar of gross domestic product. Emissions per dollar GDP have gradually decreased from 1990 until 2004. Emissions per capita have remained relatively steady from 1990 until 2003. Population has steadily increased from 1990 until 2004. Real GDP from 1990 through 2004 has increased at a higher rate than population, with the graph illustrating an upward sloping line with a short plateau in 2000 and 2001.

Figure 2-5 illustrates the data presented in Table 2-5, Recent Trends in U.S. greenhouse gas emissions and sinks by chapter/IPCC sector.

Figure 2-6 illustrates U.S. energy sector greenhouse gas sources for 2004. Fossil fuel combustion is the greatest contributor, followed by natural gas systems and coal mining. This figure also includes a pie chart, which illustrates that the energy sector represents 97.0% of all emissions.

For a detailed description of Figure 2-7, refer to the description of Figure 3-2 in Chapter 3.

For a detailed description of Figure 2-8, refer to the description of Figure 3-5 in Chapter 3.

For a detailed description of Figure 2-9, refer to the description of Figure 3-9 in Chapter 3.

For a detailed description of Figure 2-11, refer to the description of Figure 6-1 in Chapter 6.

For a detailed description of Figure 2-12, refer to the description of Figure 8-1 in Chapter 8.

Figure 2-13 illustrates the data presented in Table 2-14, U.S. greenhouse gas emissions allocated to economic Sectors from 1990 through 2004.

Figure 2-14 illustrates the data presented in Table 2-16, U.S Greenhouse Gas Emissions by “Economic Sector” and Gas with Electricity-Related Emissions Distributed (Tg $CO_2$ Eq.) and percent of total in 2004.